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MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS KIAMICHI RIVER BASIN OKLAHOMA: A REPORT ON A PORTION OF THE SOUTHEASTERN OKLAHOMA AND WESTERN ARKANSAS COMPREHENSIVE WATER RESOURCES STUDY

Public Health Service
Dallas, Texas

December 1960

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MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

KIAMICHI RIVER BASIN

OKLAHOMA

A REPORT ON A PORTION OF THE

SOUTHEASTERN OKLAHOMA AND WESTERN ARKANSAS

COMPREHENSIVE WATER RESOURCES STUDY

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Tulsa, Oklahoma

DECEMBER 1960

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FOREWORD

The Public Health Service has been asked to determine the total municipal and industrial water needs in an area that could logically be supplied from the system of three reservoirs under study. Out-of-basin and out-of-state areas have indicated an interest in water from these reservoirs and these facts constitute part of this report. This has been done with the understanding that the decision as to whether or not such transfers are to be made rests with State and non-Federal interstate agencies, not the Public Health Service.

I. INTRODUCTION

General

The Corps of Engineers, Tulsa District, in a letter dated January 6, 1959, requested the Public Health Service to estimate future water demands and to determine the value of storage capable of supplying these demands from Hugo, Tuskahoma, and Clayton Reservoirs, Kiamichi River Basin, Oklahoma. This request was made in accordance with the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, pertaining to the Water Supply Act of 1958, Title III of Public Law 85-500.

The Flood Control Act, approved July 24, 1946, authorized the construction of the Hugo Reservoir in southeastern Oklahoma as a unit of the flood control plan for the Red River. After more than a decade, a re-appraisal of this reservoir and other reservoirs within the Kiamichi Basin appears to be warranted. The Senate Public Works Committee adopted a resolution on January 28, 1955, to restudy the Kiamichi River and its tributaries to determine the feasibility of including water supply storage with flood control storage, and to re-evaluate the choice of reservoir site locations.

This report on the Hugo, Tuskahoma, and Clayton Reservoirs is part of a comprehensive study of southeastern Oklahoma and adjacent areas now in progress by the Public Health Service, Region VII. In order to prepare this report within the time limits established by the Corps of Engineers, it was necessary to utilize some data which are incomplete and techniques which lack the refinement of those being utilized in the comprehensive study. Further study of several phases of the procedures and data used in the projection of future demands will be accomplished before the issuance of the final comprehensive report. Such further study is not expected to change the conclusions of this study greatly, but will rather serve to strengthen them.

Several aspects which require further investigation include more reliable estimates of ground water availability, a closer look at alternative sources of supply, further analysis of unit water uses by industry, the relation between water cost and conservation practices, and a more complete cataloging and analysis of existing sources of supply.

In addition, a reinvestigation will be made of the Texas portion of the study area following the same procedures used for the Oklahoma portion in this study. No economic value attributable to the study projects for providing storage to meet the demands of the Texas area has been found. It is unlikely that further refinement will alter this conclusion.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in the preparation of this report are gratefully acknowledged. Special thanks are extended to the city officials, members of the Chambers of Commerce and interested citizens in Oklahoma and Texas who supplied data on their communities and their projected water requirements; to the Oklahoma Water Resources Board for information on resources in the Oklahoma portion of the study area; to the public utility companies in the study area who were exceedingly cooperative in providing data concerning their operations; to the Arkansas-Red Rivers Study Group, Public Health Service, for furnishing unpublished data on quality and flow of the Kiamichi River; and to all others who assisted in this study. A complete list of agencies and municipalities contacted appears as Exhibit A of the Appendix.

II. SUMMARY AND CONCLUSIONS

Summary

1. This study is concerned with three reservoir sites on the watershed of the Kiamichi River, one near Hugo, near the mouth of the river, and upstream sites near Tuskahoma on the main stem and Clayton on the tributary Jackfork Creek.

2. The Kiamichi River originates near the Oklahoma-Arkansas State line; it flows westward through LeFlore and Pushmataha Counties to the vicinity of Clayton, Oklahoma thence it flows in a southerly direction to its junction with the Red River. It is located entirely within the southeastern part of the State of Oklahoma.

3. The average runoff from the Kiamichi watershed is about 1,480 million gallons per day (mgd). Average runoff at the Hugo site is 1,360 mgd. Preliminary studies by the Corps of Engineers indicate the feasibility of impoundments capable of yielding 400 mgd initially at Hugo, with a possible ultimate yield of 610 mgd in combination with Tuskahoma and Clayton; 160 mgd at Clayton; and 200 mgd at Tuskahoma, for meeting municipal and industrial water supply needs.

4. A survey of localities which might benefit from water supply storage in the projects narrows the study area to three potential demand areas; one centering on the Oklahoma City metropolitan area, one comprising the local area adjacent to the reservoirs, and a third consisting of the Dallas-Fort Worth metropolitan complex in Texas.

5. For each of the three demand areas, projections are made of population growth to the year 2010, along with an analysis of the potential economic development which would support that growth.

6. A population of 1,420,000 is projected for the Oklahoma City metropolitan area in the year 2010. The corresponding water requirement projection is 436 mgd, of which about 276 mgd is for municipal and 160 mgd for industrial use. It is estimated that 139 mgd can be supplied from existing and firmly planned sources. Therefore, there will be

a potential demand for new sources with combined capability totaling 297 mgd by the year 2010.

7. In the area adjacent to the reservoirs, the projection of growth was based on a study of the natural resources. Appreciable growth is projected in forest-oriented industry, particularly pulp and paper mills. Projected water requirements for the year 2010 in this area are 5 mgd for municipal, 23 mgd for industrial, and 10 mgd for consumptive use in thermal electric power generation. From this total of 38 mgd has been subtracted 3 mgd which represents the sum of capacities of existing and committed sources which will be used in the future. Therefore, for the local area, the net potential demand from storage in Kiamichi River projects is 35 mgd.

8. Projections for the Dallas-Fort Worth area indicate that development of all sources in the Trinity valley and adjacent Texas watersheds will provide for their growing water demands until about the year 2000. After that time, water will have to be imported from more distant sources, possibly in southeastern Oklahoma. However, cost comparisons indicate that such supply could be more advantageously obtained from alternative sources than from the Kiamichi River projects. For that reason, the water demands of this area are not considered to be potential demands on Hugo, Tuskahoma, or Clayton Reservoirs.

9. Comprehensive water resources planning includes consideration of the waste disposal problems which attend municipal and industrial use of water. The ultimate responsibility and authority in the field of stream quality maintenance rests with State and local agencies. This report outlines major aspects of the complex problems involved and the possible avenues of approach to solutions.

Conclusions

1. With respect to water supply requirements, the best interests of the study area would be served by construction of the three reservoirs at staggered time intervals.

2. It is anticipated that the Hugo Reservoir may be built in the immediate future because of flood control needs. There is a present need for a small amount of water supply storage at Hugo, with the prospect that demands will increase to 35 mgd within the 50-year study period. It is recommended that storage capable of yielding 35 mgd be provided in Hugo Reservoir. The estimated annual value of this storage is $68,000.

3. Of the three reservoir sites under study, Clayton is most favorably located to supply the Oklahoma City area, with Tuskahoma second. It is estimated that water supply storage at Clayton will first be needed about 1980. The value of storage, capable of yielding 160 mgd, based upon construction in 1965 and first use of storage in 1980, is $208,000 annually.

4. Assuming prior construction of Clayton, water supply storage in Tuskahoma will be needed about the year 2000. The value of storage in Tuskahoma (for a yield of 200 mgd), based upon construction in 1965 and first use in 2000, is $100,000 annually. This yield, when added to other sources, is more than enough to supply the 2010 demand. Nevertheless, anticipating that growth will continue beyond 2010, full development of the site is recommended.

5. Because of the special circumstances surrounding the water problems of this area, storage space for low-flow augmentation (waste assimilation) is not recommended in Kiamichi River Reservoirs.

III. DESCRIPTION OF STUDY PROJECTS

Location and Physical Description[1/]

The three projects under study - Hugo, Tuskahoma and Clayton - are located in the Kiamichi River Basin in southeastern Oklahoma. The Hugo Reservoir is located on the main stem, approximately seven miles east of Hugo, Oklahoma, at river mile 17.6.

The Tuskahoma Reservoir site is also located on the main stem of the Kiamichi River at river mile 118.5, ten miles east of Tuskahoma, Oklahoma.

The Clayton Reservoir site is located on Jackfork Creek, a tributary which joins the Kiamichi at river mile 103.5, approximately three miles upstream from the confluence of Jackfork Creek and the Kiamichi River. From another point of reference, it is about three miles north of Clayton, Oklahoma.

The preliminary storage capacity for each of the several multipurpose uses is presented in Table 1.

Table 1

Preliminary Storage Capacities[1/]
Hugo, Tuskahoma, and Clayton Reservoirs

Reservoir	Flood Control Ac. Ft.	Water Supply Ac. Ft.	Water Supply MGD	Sediment Reserve Ac. Ft.	Total Storage Ac. Ft.
Hugo Alone	836,600	346,400	400	20,000	1,203,000
Hugo with Tuskahoma	665,400	517,600	630	20,000	1,203,000
Hugo with Tuskahoma & Clayton	539,600	643,400	610	20,000	1,203,000
Tuskahoma Alone	168,500	231,000	200	4,400	403,900
Clayton Alone	134,000	183,000	160	3,500	320,500
Three Reservoir System	842,100	1,057,400	970	27,900	1,927,400

Kiamichi River Basin

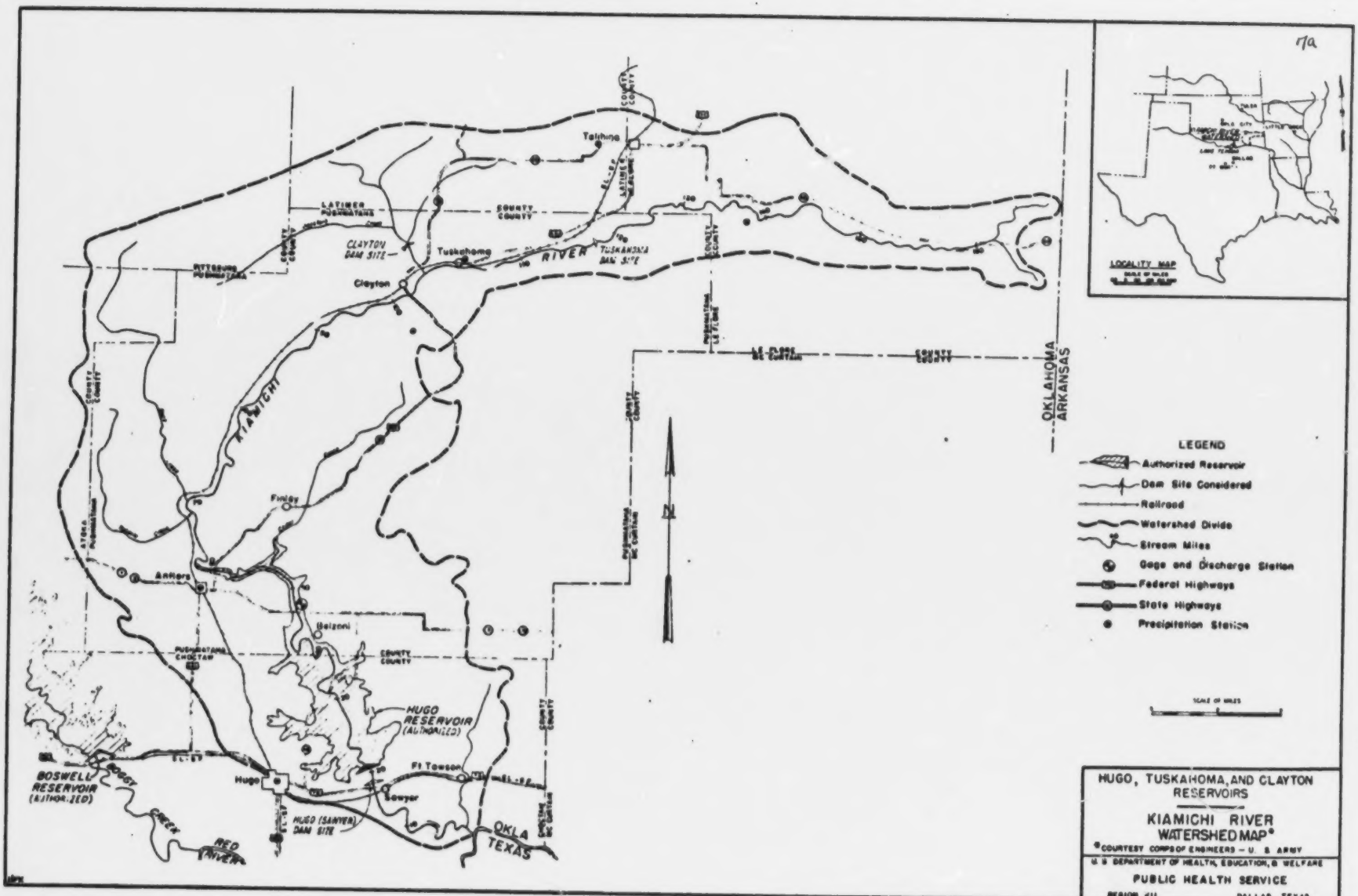
The Kiamichi River Basin, in which the study projects are located, begins in Oklahoma near the Arkansas State line. From its headwaters, the Kiamichi River flows approximately 160 miles through eastern Oklahoma until it empties into the Red River. It is located entirely within the southeastern part of Oklahoma. See map, Figure 1.

The upper 70 per cent of the basin is mountainous, covered with heavy timber growths, while the lower 30 per cent is gently rolling country, covered partly by scrub timber and used primarily for grazing. Elevations in the upper part of the basin are in excess of 1,500 feet above sea level, decreasing to about 350 feet above sea level at the mouth of the river.

The Kiamichi drains approximately 1,830 square miles. The average annual rainfall on the watershed is 46 inches. The U. S. Geological Survey has published flow records for a gaging station at Belzoni, Oklahoma, from 1925 to the present. Flow discharges at this station indicate an average flow of 1,780 cubic feet per second (cfs), with a maximum of 71,400 cfs (February 18, 1938) and a minimum flow of zero. No-flow conditions have occurred in 1930, 1932, 1934, 1939, 1940, 1943, 1952, 1954, and 1956.[2/] Average runoff at the Hugo site is 1,360 mgd.[1/]

Water Quality

The water in the Kiamichi River is presently of good quality for municipal and industrial purposes, being marred only by the presence of iron. The iron content exceeds the recommended limit of 0.3 ppm set in the Public Health Service Drinking Water Standards; however, little difficulty should be experienced in treating this water so that it will be acceptable for both municipal and industrial uses. Iron removal, furthermore, is not costly. All other chemical characteristics are well within acceptable limits, as indicated in Table 2.



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

KIAMICHI RIVER WATERSHED MAP*

*COURTESY CORPS OF ENGINEERS – U. S. ARMY

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

FIGURE 1

Table 2 3/

Water Quality Data
Kiamichi River at Belzoni, Oklahoma

Date	Sulfates				Chlorides				Total Dissolved Solids			
	Weighted PPM	Average Tons/Day	Maximum PPM	Minimum PPM	Weighted PPM	Average Tons/Day	Maximum PPM	Minimum PPM	Weighted PPM	Average Tons/Day	Maximum PPM	Minimum PPM
1947-48	6	23	13	3	6	21	41	3	61	228	98	44
1948-49	5	33	13	3	4	25	9	3	59	372	92	44
1949-50	5	40	9	3	4	33	7	3	66	584	84	48
1950-51	6	28	8	4	6	26	12	3	71	336	90	59
1951-52	7	28	10	5	6	24	10	5	65	260	82	59
1952-53	6	31	13	4	5	25	15	4	51	281	106	25
1953-54	7	15	14	4	6	14	36	5	67	151	145	49

Chemical Analysis, in parts per million, water year October 1953 to September 1954

Date of Collection	Mean Dischg. CFS	SiO_2	Fe	Ca	Mg.	Na	K	HCO_3	CO_3	F	NO_3	B	Hardness as $CaCO_3$ Ca., Mg.	Hardness as $CaCO_3$ Non-carbonate	Percent sodium	Sodium Adsorption Ratio	Specific Conductance (Micromhos @ 25°C)	pH
Oct.1-31,'53	10.7	5.0	0.35	4.1	2.6	6.3	2.1	28	0	0.3	0.5	0.74	22	0	36	0.6	73.1	7.0
Nov.1-5,7-23, 25,26,28-30	28.3	---	---	5.6	1.5	7.5	---	30	0	---	0.6	---	20	0	45	1.3	80.7	6.8
Nov.6,24,27	72.3	---	---	14.0	3.7	21.0	---	52	0	---	1.1	---	50	7	48	1.3	217	7.3
Dec.1-3	71.7	---	---	15.0	3.1	23.0	---	57	0	---	1.8	---	50	3	50	1.4	228	7.2
Dec.4-31	358	---	---	4.8	1.2	5.4	---	18	0	---	0.8	---	17	2	41	0.6	65.8	6.8
Jan.1-31,'54	3,465	8.0	0.70	2.7	1.3	5.4	1.9	13	0	0.3	1.2	0.11	14	3	42	0.6	52.5	6.5
Feb.1-28	703	7.9	0.55	3.2	1.5	5.1	1.3	14	0	0.0	0.0	0.27	14	3	39	0.6	55.9	6.6
Mar.1-31	176	8.1	0.15	4.7	2.5	7.9	1.3	15	0	0.0	0.0	0.27	22	10	42	0.7	89.8	6.7
Apr.1-30	1,292	6.8	0.35	4.3	2.0	6.6	1.6	17	0	0.2	0.0	0.27	19	5	39	0.7	77.9	6.8
May 1-31	3,754	8.1	0.55	4.0	1.2	4.6	1.6	20	0	0.8	0.1	0.27	15	0	35	0.5	57.0	7.0
June 1-30	124	10.0	0.20	4.2	3.8	5.1	2.0	25	0	0.3	0.4	0.00	26	6	28	0.4	73.8	7.2
July 1-29	3.83	10.0	0.12	5.3	3.0	8.2	1.5	32	0	0.1	1.1	0.00	26	0	39	0.7	102	7.2
Aug.2-7	0.28	9.0	0.00	5.4	3.5	7.9	1.9	34	0	0.1	2.4	0.00	28	0	36	0.6	99.1	7.3
Sep.30	72.0	---	---	8.0	2.4	9.0	---	35	0	---	4.0	---	30	2	39	0.7	109	7.4
Weighted Average	830	---	---	3.6	1.4	5.3	---	17	---	---	0.5	---	15	1	43	0.6	59.4	---

IV. DETERMINATION OF STUDY AREA

The area considered to have a possible municipal and industrial water demand which could be supplied from storage in the Hugo, Tuskahoma, and Clayton Reservoir projects consists of central and southeastern Oklahoma and northeastern Texas. In order to facilitate the projection of water demands, the overall study area was divided into several subareas. See map, Figure 2, and Table 3.

Table 3

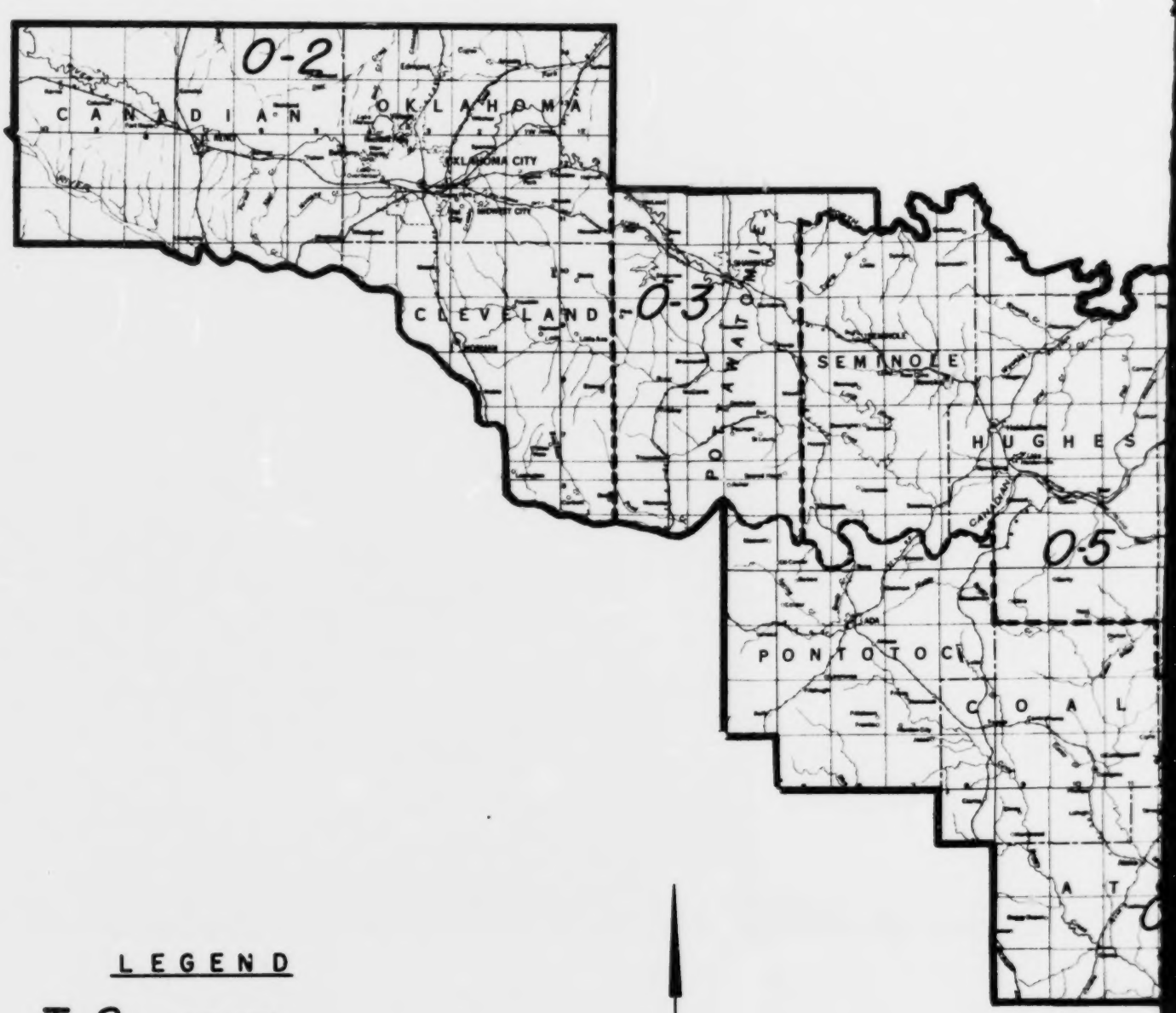
Composition of Subareas

Subarea	Political Subdivisions Included
O-1	Pushmataha, Latimer, and Choctaw Counties, Oklahoma
O-2	Oklahoma, Canadian, and Cleveland Counties, Oklahoma
O-3	Pottawatomie County, Oklahoma
O-4	Atoka, Coal, and Pontotoc Counties, Oklahoma
O-5	Hughes, Pittsburg, and Seminole Counties, Oklahoma
T-1	Dallas, Tarrant, Collin, Denton, Ellis, and Johnson Counties, Texas
T-2	Fannin and Lamar Counties, Texas

The study area and subareas were determined in the following manner:

1. The area immediately adjacent to the reservoir sites is the first logical demand area to be investigated. Therefore, Pushmataha, Latimer, and Choctaw Counties, Oklahoma, have been included as Subarea O-1.

2. The large volume of water which can be developed in the Kiamichi Basin appears to be far in excess of the requirements of the immediate area, Subarea O-1. Therefore, an investigation was made to determine the logical extent of the demand area. The major demand areas were determined to be the Oklahoma City area and the Dallas-Fort Worth area. The Standard Metropolitan Area (SMA) is considered to be the smallest breakdown which could be employed for the purpose of projection. These SMA's are the



LEGEND

T-2 SUB-AREA

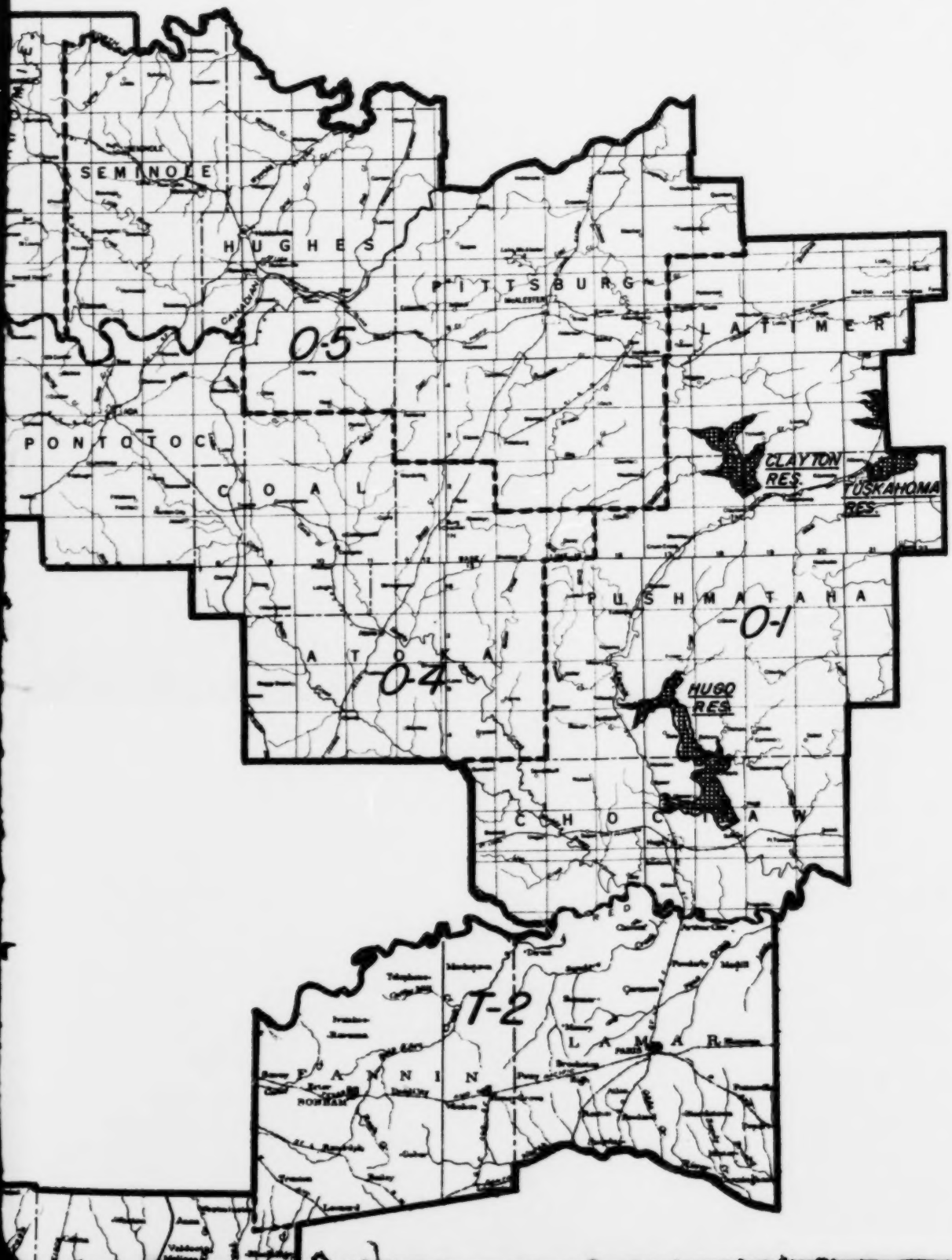
SUB-AREA BOUNDARY

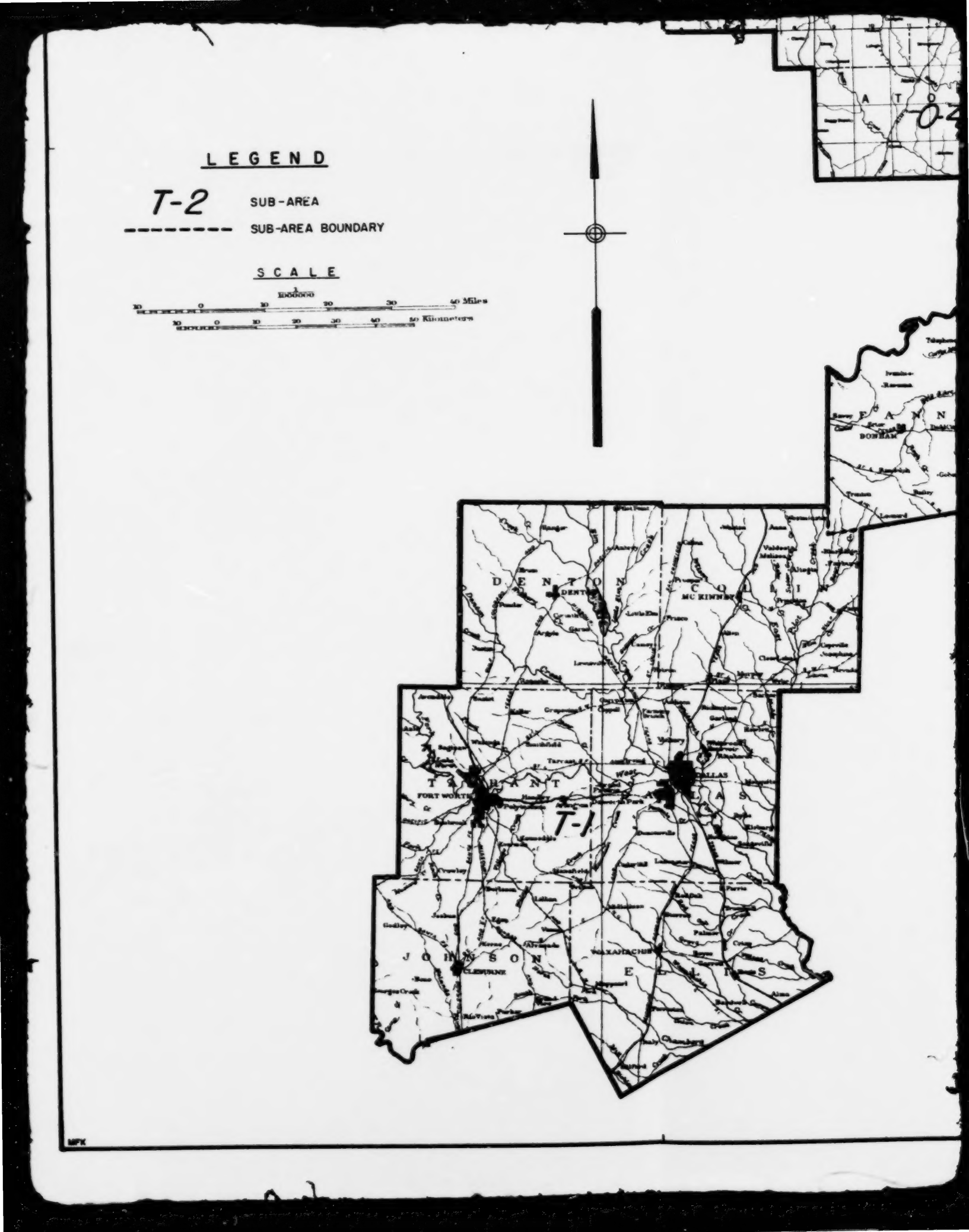
SCALE

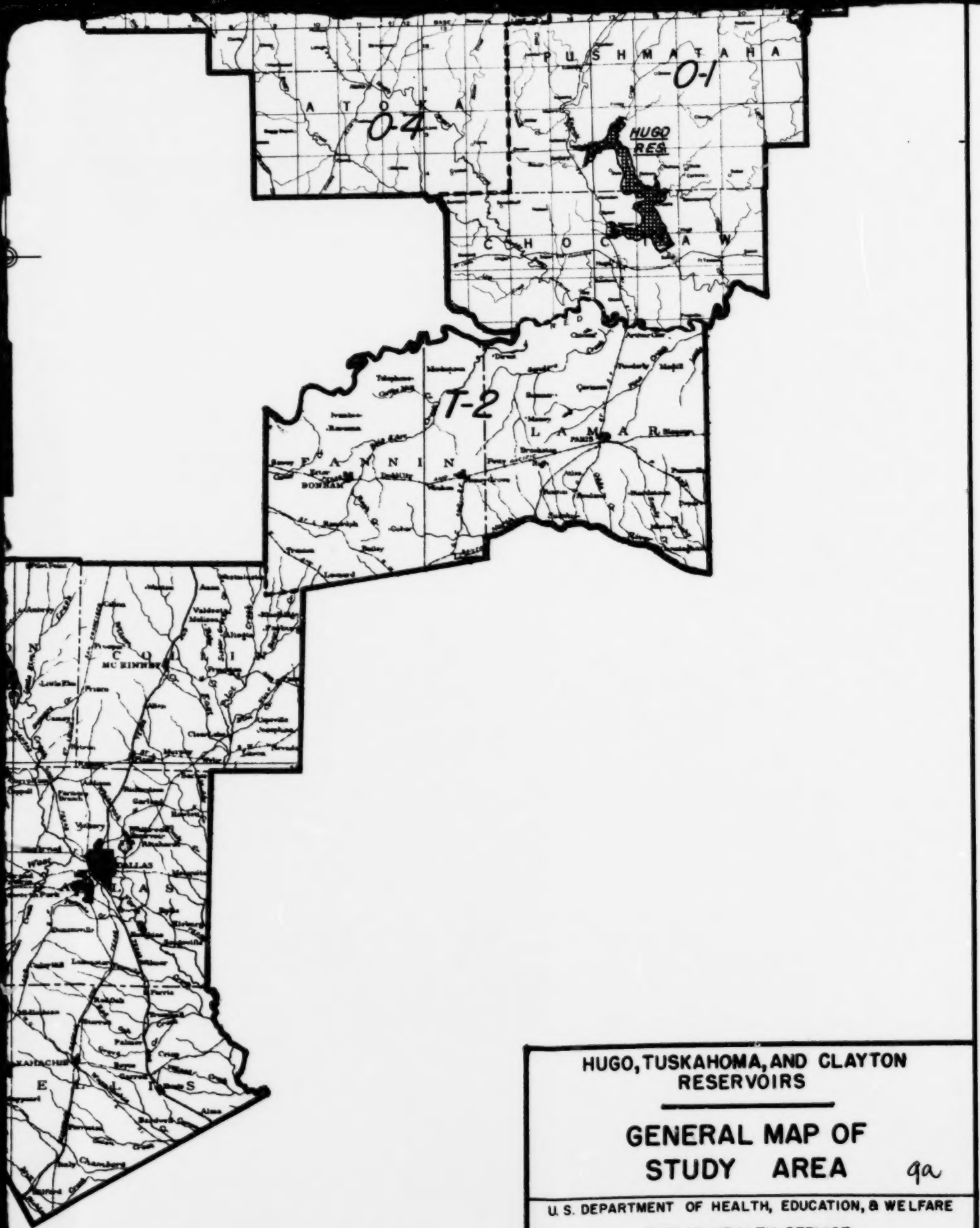
1:1000000

30 0 10 20 30 40 Miles

30 0 10 20 30 40 50 Kilometers


SEMINOLE
HUGHES
PITTSBURG
LATIMER
0-5
PONTOTOC
COAL
CLAYTON RES.
TUSKAHOMA RES.
PUSHMATAHA
0-1
ATOKA
0-4
HUGO RES.
CHOCTAW
T-2
LAMAR
PANNIN


LEGEND
T-2
SUB-AREA
SUB-AREA BOUNDARY
SCALE
1/1000000
30 0 30 30 30 40 50 Miles
30 0 30 30 30 40 50 Kilometers
T-1
T-2
DENTON
COLLIN
HUNT
DALLAS
ROCKWALL
KAUFMAN
JOHNSON
ELLIS
FANNIN
FORT WORTH
DENTON
MC KINNEY
DALLAS
CLEBURNE
WAXAHACHIE
BONHAM
MFX



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

GENERAL MAP OF STUDY AREA

9a

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PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

FIGURE 2

Oklahoma City SMA, consisting of Oklahoma, Cleveland and Canadian Counties, Oklahoma; and the Dallas and Fort Worth SMA's, consisting of Dallas, Tarrant, Johnson, Ellis, Denton, and Collin Counties, Texas. These SMA's were designated Subarea O-2 and Subarea T-1, respectively.

3. An investigation was made to determine the routes by which water could be transmitted from the reservoir sites to the large-demand areas. It was assumed that areas of relatively small water demand could not afford a high transmission cost. It would be possible, however, for them to purchase water from a pipe line serving a large-demand area. Counties along the anticipated pipe-line routes to Subareas O-2 and T-1 were grouped to facilitate projection, thereby determining these subareas:

   Subarea O-3, Pottawatomie County, Oklahoma

   Subarea O-4, Atoka, Coal, and Pontotoc Counties, Oklahoma

   Subarea O-5, Hughes, Pittsburg, and Seminole Counties, Oklahoma

   Subarea T-2, Fannin and Lamar Counties, Texas

V. THE ECONOMIC SITUATION

General Prospectus

Analysis of the economy of the study area, as a step in establishing the demand for water, necessarily involves consideration of the national economy because of the influence of national factors on future developments. Therefore, the following broad assumptions relative to the level of the national economy during the 50-year period of analysis are of major importance:

1. Some variation in the level of economic activity may be expected from time to time, but no serious economic depression will occur.

2. No major war will occur, but a high level of military and foreign aid expenditure will prevail.

3. The domestic-nonmilitary-public sector of the economy, i.e., expenditures for public works at all levels of government, will continue at least at the present rate.

4. The population of the Nation will double during the 50-year period.

The effect of these conditions will be to keep the labor force close to fully employed and to provide an impetus for advancement in living standards and a vast increase in demand for goods and services of all kinds.

Production, Employment, and Population

The capabilities of the study area in regard to this assumed economic growth are a product of its resource base in conjunction with the usual array of locational economic factors buttressed by certain intangibles such as local leadership and zeal of the populace. The primary importance of natural resources as the key factor in the development of the area is apparent in this methodology.

The development of the area, though dependent, for its initial impetus and sustained advance, on these available natural resources, is not confined solely to manufacturing industries based on those resources. The nonresource-oriented manufacturers - those who do not depend on the natural resources of the area - are also significant. These manufacturers combine partly finished and component products into finished products.

Many firms making this type of product can reasonably be expected to establish in the study area as the general economy develops. The extent of their establishment can be predicated on a percentage of the national anticipated growth in these products, based on past relationships between the area output and the national output, and allowing for increased industrial diversification and enlarged markets in the study area and the Nation.

In addition to the above industries, there are service industries, which include operations such as commercial establishments, medical centers, schools, and government.

Total economic activity is thus a composite of the production and distribution of goods and the provision of services. Employment in these two categories, which include the entire labor force, bears a close relationship to total population.

Data of sufficient detail for the analysis of employment were available for 1940 and 1950. For 1960, data had to be obtained from field survey, confined chiefly to the Oklahoma section of the study area. The number of employees in mining, forestry, and all categories of manufacturing was obtained directly from industrial plants, from State agencies, and from Chambers of Commerce. Plans for industrial expansion and the probable extent and use of mineral resources were determined by interviews with industrialists, government officials, university staff members, trade organizations, and others.

Extractive Industries

Agriculture

The present economy of southeastern Oklahoma displays depressed conditions through most of the area. The main factor contributing to these conditions had been the dependence upon a declining agricultural base.

Agricultural employment in the Oklahoma study area has decreased from 39,971 in 1940, to 25,817 in 1950, and is down to an estimated 16,930 in 1960.[4,5] The number of farms, cropland harvested, and the value of crops sold have experienced a sharp decrease during this period. There has been, however, a trend toward livestock production since 1944, as measured by an increase in the dollar value sold. This trend toward livestock production has continued to 1960. Although total agricultural production has remained fairly stable, the labor force required has decreased, which has been primarily responsible for the marked decline in rural population.[6,7] Data indicating these agricultural trends appear in Table 4.

Table 4 [6,7]

Number of Farms, Croplands Harvested
And Value of Crops and Livestock and Livestock Products
Sold in Subareas 0-1, 0-2, 0-3, 0-4, 0-5 in 1944, 1949, and 1954

Year	Number of Farms	Cropland Harvested (acres)	Value of Crops Sold ($)	Value of Livestock & Livestock Products Sold ($)
1944	28,818	1,229,682	14,945,108	19,350,808
1949	25,262	944,052	15,109,754*	20,789,242*
1954	20,571	742,996	11,937,428*	23,310,132*

* Adjusted to the 1944 value of the dollar.

Agriculture likewise continues to be an important segment of the rural economy of the subareas in Texas. Although substantial decreases have occurred in the rural population and the number of farms since 1949, agricultural production has revealed no significant decrease as measured by monetary returns from crop and livestock production. The decrease in the rural population and the number of farms, following the national trend, is due to increased mechanization, increased productivity and farm consolidation. Table 5 presents agricultural data for Subareas T-1 and T-2.

Table 5 [6,7]

Number of Farms, Croplands Harvested
And Value of Crops and Livestock and Livestock Products
Sold in Subareas T-1, T-2 in 1944, 1949, and 1954

Year	Number of Farms	Cropland Harvested (acres)	Value of Crops Sold ($)	Value of Livestock & Livestock Products Sold ($)
1944	31,989	1,972,254	40,634,337	21,418,873
1949	28,022	1,774,438	54,330,380*	25,735,726*
1954	23,047	1,562,812	36,949,263*	25,518,034*

* Adjusted to the 1944 value of the dollar.

Minerals

The extraction of minerals is an important activity in the economy of this region. In the study area of both States, petroleum, stone, sand, gravel, clay, and limestone are extracted. In addition, coal, natural gas, and natural gas liquids are mined in the Oklahoma study area.[8-13]

Total employment in mining in the Oklahoma study area in 1960 was 10,400. The number of workers varied within narrow limits for the last 20 years - in 1940, there were 10,534 employed in mining and in 1950, 10,470. Approximately half as many are employed in the Texas study area.4,14/

The total value of mineral production for the seven-year period from 1952 to 1958 averaged $127,000,000 annually in the Oklahoma study area (0-1, 0-2, 0-3, 0-4, 0-5) and $28,000,000 in the Texas study area (T-1 and T-2). The combined value for both areas exhibits a stable condition. See Table 6.

Table 6 15/

Value of Mineral Production, 1952-1958
(Figures in millions of dollars)

Area	1952	1953	1954	1955	1956	1957	1958
I (Okla)	125	133	126	127	127	131	121
II (Tex)	19	19	27	32	31	28	37
Total	144	152	153	159	158	159	158

Explorations for petroleum and gas, the most important mineral resources of the area, are continuing. In the Oklahoma study area, 76 exploratory wells were drilled in 1958. Seventeen of these were producing wells; the remaining 59 were dry. Drilling in proved fields was more successful. Of the 459 wells drilled in 1958, 264 were producing; only 195 were dry.15/ Wells in much of the area are undergoing secondary recovery operations.

Forest Resources

The area of commercial forest is confined to the southeastern part of the Oklahoma study area. This area includes Atoka, Coal, Latimer, Pushmataha, Choctaw, and Pittsburg Counties. The part of the study area lying in Texas does not have commercial forests of sufficient economic value to warrant consideration.16/

There are 2,256,000 acres of forest land in the six counties mentioned above. The growing stock in 1955 is estimated to total 420 million cubic feet of which 133 million is softwood and the remaining 287 million, hardwood. The standing volume of saw timber is 1,175 million board feet. The net annual growth amounts to approximately 35 million cubic feet.17,18/

Optimum use has not been made of the present forest land. The present pattern of ownership (most of the forest lands are in private holdings of less than 500 acres) has precluded good management practices. In much of the area, an acre supports less than 1,500 board

feet. More effective use of growing space is impeded by large numbers of cull hardwoods. Foresters have expressed the opinion that with application of good forestry practices, the net annual increment of growing stock would nearly double.17/

Logging and primary processing and manufacturing of timber products employed 475 in 1960 in the six counties of Oklahoma. Although not all of these workers were employed for the entire year, forestry ranked as one of the most important basic industries in these counties.

Manufacturing Industries

Manufacturing is becoming of greater importance in the Oklahoma portion of the study area. However, the proportion of the total labor force in the area employed in this category is considerably less than the national ratio. The Oklahoma City metropolitan area had only 9.9 per cent of the labor force in manufacturing in 1950, as compared to the national urban average of 29.4 per cent.4,19/ The relative increased importance of manufacturing is indicated by a 1.2 per cent growth in employment in the Oklahoma City area and an increase of 3.6 per cent in the remainder of the Oklahoma area between 1950 and 1960. National figures for 1960 are not available for comparison, but it is reasonable to assume that the disparity in employment between the Nation and the study area has decreased. Manufacturing plays a more significant role in the Texas study area than in Oklahoma. The 1950 figures show 18.7 per cent of the labor force in manufacturing in the Texas study area.20/

Employment in resource-oriented industries is proportionately greater in the Oklahoma study area relative to its total manufacturing employment than it is in the Nation. However, there has been a shift toward a greater increase in nonresource-oriented manufacturing. In the Oklahoma study area, nonresource-oriented manufacturing increased more between 1950 and 1960 than did manufacturing based on resources. The greatest increase was in the fabrication of metals, machinery, other durable goods and apparel. See Table 7.

Another index of rise in manufacturing activity is the value added by manufacture. The total value added in the entire study area tripled in a span of eleven years from $500 million in 1957 to $1.5 billion in 1958. During this same time span, the national increase was 91 per cent so that all of the subareas exceeded the national rate except the Oklahoma City area, which approximately equalled it.21/ See Table 8.

Table 7

Percentage Distribution of the Labor Force
1950 and 1960**

	0-2		0-1, 0-3 0-4, 0-5		U. S. Total	U. S. Urban	T-1, T-2
	1950 4/	1960**	1950 4/	1960**	1950 19/	1950 19/	1950 20/
Farm	4.3	2.2	25.2	20.0	11.6	1.0	6.4
Forestry & Fisheries	*	*	*	*	0.2	0.1	*
Mining	3.0	3.2	7.6	6.2	1.6	0.9	1.0
Manufacturing	9.9	11.1	6.6	10.2	24.7	29.4	18.7
Resource-oriented	(5.2)	(5.3)	(3.8)	(4.2)	(10.0)	(11.1)	(6.4)
Furniture, Lumber, & Wood Products	0.7	0.5	1.6	1.0	2.0	1.3	0.9
Primary Metals	0.3	0.4	*	*	2.0	2.5	0.3
Food & Kindred Products	3.2	3.0	1.5	2.6	2.4	2.9	3.2
Chemical & Allied Products	0.3	0.4	0.2	0.1	1.1	1.4	0.7
Other Nondurables	0.7	1.0	0.5	0.5	2.5	3.0	1.3
Nonresource-oriented	(4.7)	(5.8)	(2.8)	(6.0)	(14.7)	(18.3)	(12.3)
Fabricated Metals, Machinery, & Other Durables	2.8	4.1	1.3	2.2	9.1	11.7	8.0
Textile & Apparel	0.2	0.3	0.8	3.0	3.9	4.4	2.5
Printing, Publishing, NEC	1.7	1.4	0.7	0.8	1.7	2.2	1.8
Total Basic	17.2	16.5	39.4	36.4	38.1	31.4	26.1
Total Service	79.8	78.5	56.3	58.6	57.6	62.8	70.9
Unemployed	3.0	5.0	4.3	5.0	4.3	5.8	3.0
Total Labor Force (in thousands)	158	203	76	62	59,072	38,406	514

* Less than 0.1 per cent.
** Published data for 1960 was not available. Data for Oklahoma study area was obtained from field surveys.

Table 8

Value Added by Manufacture[21/]
1947, 1954, 1958
(Figures in thousands of dollars)

Area	1947	1954	1958	Percent Increase 1947-1958
0-1, 0-3, 0-4, 0-5*	$ 6,315	$ 18,064	$ 28,908	88
0-2	77,979	112,062	146,648	358
T-1	400,541	904,323	1,371,495	242
T-2*	7,081	16,493	21,670	206
TOTAL	$491,916	$1,050,942	$1,568,721	219

*Only counties for which data was available for all three years were included.

Service Industries

The provision of governmental service and facilities, business and personal services, the distribution of goods, the furnishing of financial and insurance services, as well as other similar conveniencies, constitutes a large segment of the economic activity of the area. These service categories employ over half of the total labor force.

Metropolitan areas typically have a greater proportion of the labor force in service employment than do rural areas. In the Oklahoma City area, for example, three out of four in the labor force were employed in providing services whereas in the nonmetropolitan areas, it was only slightly more than two out of four.

The proportion of the study area's labor force employed in service industries remained essentially the same between 1950 and 1960. Although no published data are available which show the national average in employment for all service workers during the last decade, an approximation of the average can be computed by comparing employment in retail, wholesale, and service industries, which together employ a significant part of the service workers as defined in this report. The number of employees between 1948 and 1958 is shown on Table 9.

When employment in these services is compared to estimated populations during 1948 - 1958, the proportion of the labor force in these categories varied within narrow limits. Employment in the service industries in 1960, therefore, was judged to have remained practically unchanged since 1950.

Table 9

Number of Employees
Retail, Wholesale and Service Trades[22-39]
1948, 1954 and 1958

Year	0-2	0-1, 0-3 0-4, 0-5	T-1	T-2
1948	39,924	13,566	141,329	5,208
1954	45,138	12,626	152,464	4,122
1958	53,385	12,369	180,853	4,391

Population

The population for Subareas 0-1 through 0-5 was 708,125 in 1960. This reflects an increase of slightly less than 60 per cent since 1920; during the same period the national increase was 70 per cent. Some divergent trends within the area are noteworthy. The Oklahoma City Standard Metropolitan Area (0-2) increased steadily from 156,974 in 1920 to 508,581 in 1960, or an increase of 222 per cent. During the same time span, the remainder of the Oklahoma study area decreased 30 per cent. The greatest period of decrease in these counties outside the Oklahoma City Standard Metropolitan Area was between 1940 - 1960 when the population dropped 40 per cent, from 325,261 to 199,544. The decline was, however, almost entirely in the rural areas. The total in cities of more than 1,000 population was 110,317 in 1940, and 106,349 in 1960, or a decrease of 4 per cent. In contrast, the rural areas during the 20-year period decreased 59 per cent, from 214,944 in 1940 to 87,834 in 1960.[40-42] The primary reason for the marked decline in the counties of southeastern Oklahoma was the decrease in agricultural employment. Population data are presented in Table 10.

Table 10

Population, 1920 - 1960[40-42]

Area	1920	1930	1940	1950	1960
0-2	156,984	274,801	299,216	392,439	508,581
0-1, 0-3, 0-4, 0-5	283,194	335,898	325,261	241,180	199,544
TOTAL	440,178	610,699	624,477	633,619	708,125
T-1	540,905	689,499	783,050	1,136,144	1,642,057
T-2	120,211	102,830	104,347	83,250	63,456
TOTAL	661,116	792,329	887,397	1,219,394	1,696,076

The population of Subareas T-1 and T-2 has shown a phenomenal growth since 1920. The population increased from 661,166 in 1920 to 1,696,076 in 1960. The Dallas-Fort Worth SMA's have shown the most dramatic growth. Dallas' metropolitan area increased from 350,819 in 1920 to 1,074,756 in 1960, while Fort Worth's metropolitan area increased from 190,086 in 1920 to 557,864 in 1960. A portion of the study area (T-2) has been losing population. This decrease was due to the decline in agricultural employment. Table 10 reveals the population trend for Subareas T-1 and T-2 from 1920 to 1960.[40-42]

VI. THE ECONOMIC OUTLOOK

Economic Projections

The southeast Oklahoma area is adequately provided with the factors which permit economic growth. That is, transportation, fuel and power, and labor supply are either already available or will readily accompany the population and market increase arising from the utilization of the natural resource base. In addition to these factors, the geographic setting of the area is attractive from the standpoint of regional distribution of products, since the large markets of the Midwest and Gulf are within a day's trucking distance. Climate presents no particular hazard either to persons or to industrial operations. The recreational prospects are also very good, especially because of the reservoirs and wooded highlands. In total, therefore, the general picture is hopeful. A particularized projection of the prospects follows.

There is a promising outlook for agriculture in the study area. Based on projected national population growth, agricultural production may be expected to increase by 100 per cent in the study area by 2010. It is apparent that much of the agricultural production facilities of the Nation will be called upon for greater efforts if the future requirements for food and fiber are to be met. Sufficient resources exist in the study area to permit an increase in agricultural output. At present, the farm lands are under utilized due in part to the relatively low productivity of the shallow soil. The soil is, however, well adapted to the production of livestock and livestock products. Although total agricultural production is expected to double in the study area, no increase in the farm labor force is anticipated. With anticipated technological advances, production can be expected to double with no increase in farm employment.

Another resource of the Oklahoma study area that can be expected to contribute to increasing national demand is timber. The present rate of harvest is less than the net growth and with the increase in net growth that can be expected with good forestry management practices, a significant increase in employment can be expected in the forestry industry. The timber resources can support an employment increase of 75 per cent in the lumber and wood products industries as well as a medium-size pulp and paper mill.

The mining industry likewise has promise for expansion. A variety of minerals are available. These include petroleum, gas, coal, limestone, sand and gravel, asphaltic materials, sandstone, brick clay, granite, and wool rock. Although petroleum extraction will probably decrease, the mining of other minerals can be expected to increase, particularly natural gas. Given a favorable demand situation, with consideration for known and probable reserves, it

seems reasonable to expect employment in the mineral extractive industries in the Oklahoma study area to increase from 10,418 in 1960 to 15,600 by 2010.

Processing and manufacturing based upon the use of these resources are anticipated to form an important part of the economic base of a large part of the study area. The more important resource-oriented industries which have a likelihood of expanding significantly include: food processing; furniture, lumber and wood manufacturing; pulp and paper mills; petroleum, gas and coal products; chemicals; and stone, clay and glass products. These industries rely heavily upon the local availability of most of the raw materials needed. It is recognized that costs of manufacturing and distribution in the resource area compared to these same costs in the market area may change and therefore the projected pattern may be modified. It seems reasonable, however, to assume with the evidence now at hand, that the study area will be at no competitive disadvantage. Accordingly, employment in these industries can be expected to increase to coincide more nearly with the national pattern. For the Oklahoma City metropolitan area, an increase from 5.3 per cent of the labor force in 1960 to 8.2 per cent in 2010 seems probable. A similar rate of growth for the remaining Oklahoma study area is forecast.

In addition to resource-oriented manufacturing, there is nonresource-oriented industry. This term refers to those industries that produce products wherein the materials per se are a relatively insignificant part of the total cost. Labor costs both in production and market predominate, hence the proximity of the raw materials is of less importance. This category - nonresource-oriented manufacturing - is well developed in the Dallas-Fort Worth area, but is relatively underdeveloped in the Oklahoma City SMA as well as in the rest of the Oklahoma and Texas study area. Rapidly growing markets in and adjacent to the study area will encourage a vast expansion in the manufacturing of metal products, electrical equipment and appliances, transportation equipment, apparel, and miscellaneous household and personal goods.

The relative size of the labor force to be engaged in manufacturing in the Oklahoma City metropolitan area by the year 2010 was assumed to be similar to that which now exists in industrial cities of the south central United States - Fort Worth, Tulsa, and Houston. In these cities, the proportion employed in manufacturing averaged 21.0 per cent.[4,19,20] For the nonmetropolitan part of the Oklahoma study area, forecast manufacturing employment was predicated upon the resource potential for resource-oriented and upon past trends for nonresource-oriented manufacturing employment.

In addition to basic employment in the extractive and manufacturing industries, there are a large number of employees engaged in financing, transporting, and selling the goods produced by the

Table 11

Projected Percentage Distribution of the Labor Force
For Oklahoma Study Area
2010

	0-2	0-1	0-3	0-4	0-5	Weighted Average 0-1, 0-3 0-4, 0-5
Farm	0.6	19.2	6.1	15.9	12.5	11.9
Forest & Fisheries	*	0.5	*	*	0.1	*
Mining	1.3	1.7	5.4	12.9	8.6	11.7
Manufacturing	21.0	19.5	16.4	12.9	14.8	12.4
Resource-oriented	(8.2)	(14.2)	(6.6)	(5.1)	(6.9)	(4.5)
Furniture, Lumber & Wood Products	1.3	5.8	0.4	1.2	1.6	0.5
Primary Metals	0.6	*	*	*	0.1	0.3
Food & Kindred Products	3.6	2.0	5.7	2.6	3.1	2.0
Chemicals & Allied Products	1.0	0.6	0.1	0.6	0.4	0.4
Other Nondurables	1.7	5.8	0.4	0.7	1.7	1.3
Nonresource-oriented	(12.8)	(5.3)	(9.8)	(7.8)	(7.9)	(7.9)
Fabricated Metals, Machinery, & Other Durables	7.5	1.4	4.6	5.4	2.9	1.0
Textile & Apparel	3.0	3.3	4.1	1.9	4.3	6.3
Printing, Publishing, NEC	2.3	0.6	1.1	0.5	0.7	0.6
Total Basic	22.9	40.9	27.9	41.7	36.0	36.0
Total Service	72.1	54.1	67.1	53.3	59.0	59.0
Unemployed	5.0	5.0	5.0	5.0	5.0	5.0
Total Labor Force	539,600	17,700	26,100	21,600	100,100	34,700
Total Population	1,420,000	52,000	68,500	63,500	286,000	102,000

* Less than 0.1 per cent.

"production" workers and providing personal service. As the number of basic production workers increases, the number of workers providing services increases also. The proportional increase in basic and service workers will vary among areas, depending upon the influence of the many service market areas. The number of service workers were judged on the basis of past trends.

Total anticipated employment was projected on the basis of the preceding analysis. To this was added an assumed unemployment of 5 per cent to establish the total labor force. The total population was determined by applying the historic trend of the ratio of labor force to population. The per cent distribution of the labor force for the Oklahoma study area is shown in Table 11.

Population Projections

All three metropolitan areas in the study area have been growing at a more rapid rate than the average of other metropolitan centers of the Nation. With the expansion potential that exists in the study area, the economic base will continue to support an increasing population.

Population projections are presented in Figures 3 through 10 and Table 12.

Table 12

Population Projections, By Subarea
1975, 2010

Subarea	1960 [42/]	1975	2010
0-1	32,271	32,000	52,000
0-2	502,707	680,000	1,420,000
0-3	41,250	46,000	68,500
0-4	43,763	43,800	63,500
0-5	76,899	75,000	102,000
T-1	1,642,057	2,480,000	6,580,000
T-2	63,456	78,500	130,000

Many factors were considered in formulating these projections. Not only was the employment approach used as previously explained, but consideration was also given to past trends. In the subareas where the rural population is a significant part of the total, the urban segment is expected to gain while the rural population will probably remain essentially stationary from 1960 to 2010. The metropolitan areas are expected to gain significantly. The factors used to project the population of the three metropolitan areas include: (1) resource and employment analysis; (2) growth comparisons with other metropolitan areas that were of similar size to the cities

of the study area in the past; (3) the ratio of growth between these cities and the total national population; and (4) the growth between these cities and the national urban population.

The results of the forecasts are compared on Table 13 to those predicted by the U. S. Bureau of Census and Resources for the Future.

Table 13

Standard Metropolitan Area Projections for 2010
Compared with Resources for the Future
And Bureau of Census Projections

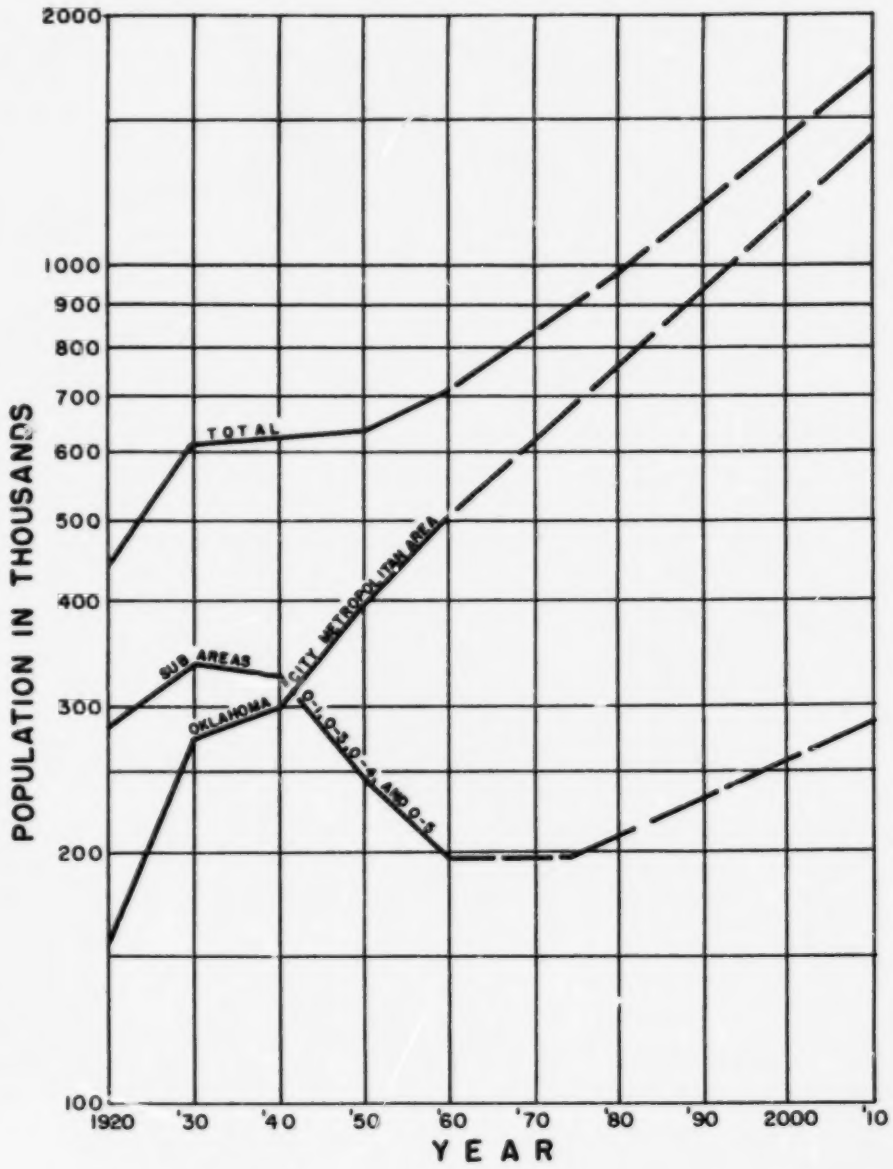
	Oklahoma City	Dallas	Fort Worth
Public Health Service	1,420,000	3,700,000	2,880,000
R.F.F. 43/***			
Assumption 1*			
High	1,870,000	5,230,000	4,900,000
Medium	1,300,000	3,700,000	3,600,000
Low	1,113,000	2,810,000	2,705,000
Assumption 2**			
High	2,200,000	5,010,000	4,700,000
Medium	1,450,000	3,700,000	3,400,000
Low	1,205,000	2,810,000	2,705,000
Bureau of Census 43/***			
High	---------	5,010,000	4,000,000
Low	---------	3,700,000	2,905,000

* Assumption No. 1 - The average annual migration of the period 1950-1958 is assumed to prevail to 1970 and then the average annual amount of migration of the 1940-1958 period is assumed to prevail for the period 1970-1980.

** Assumption No. 2 - Average annual amount of migration during the period 1958 to 1980 is assumed to equal one-half that of the 1940-1958 period.

After 1980 for both assumptions - it was assumed that the change in the proportion of population in each state between 1980 and 2000 will be the same as the change in the proportion that occurred between 1970 and 1980, as implied by the projections for these dates.

*** Two adjustments were made to the forecasts of the Bureau of Census and R.F.F. First, the metropolitsn area definition used by the Bureau of Census was that which existed in 1950. The additional counties added to the metropolitan definition in 1960 were added and were assumed to have the same rate of growth as that predicted for the original counties. Second, the projection was made to the year 2000. This was extended to 2010 assuming the same rate of increase as forecast for the earlier period.



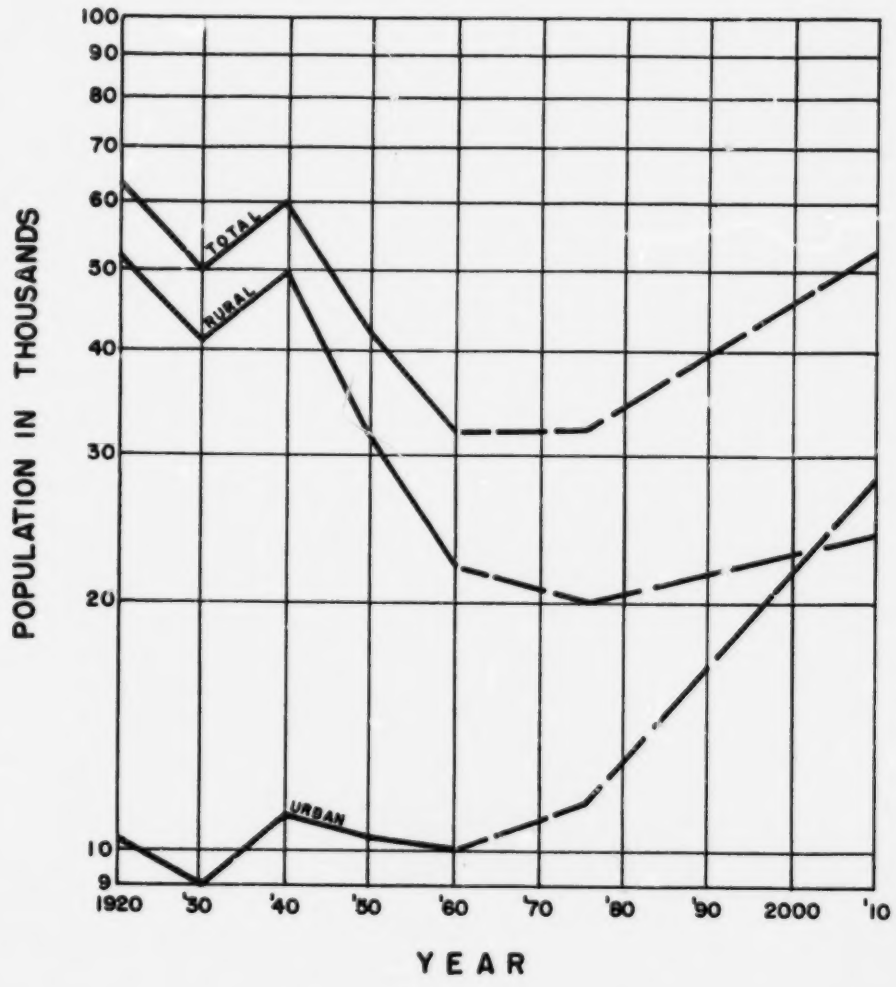
HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTION
OKLAHOMA SUMMARY

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

MFK

FIGURE 3



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTIONS
SUB-AREA O-1

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

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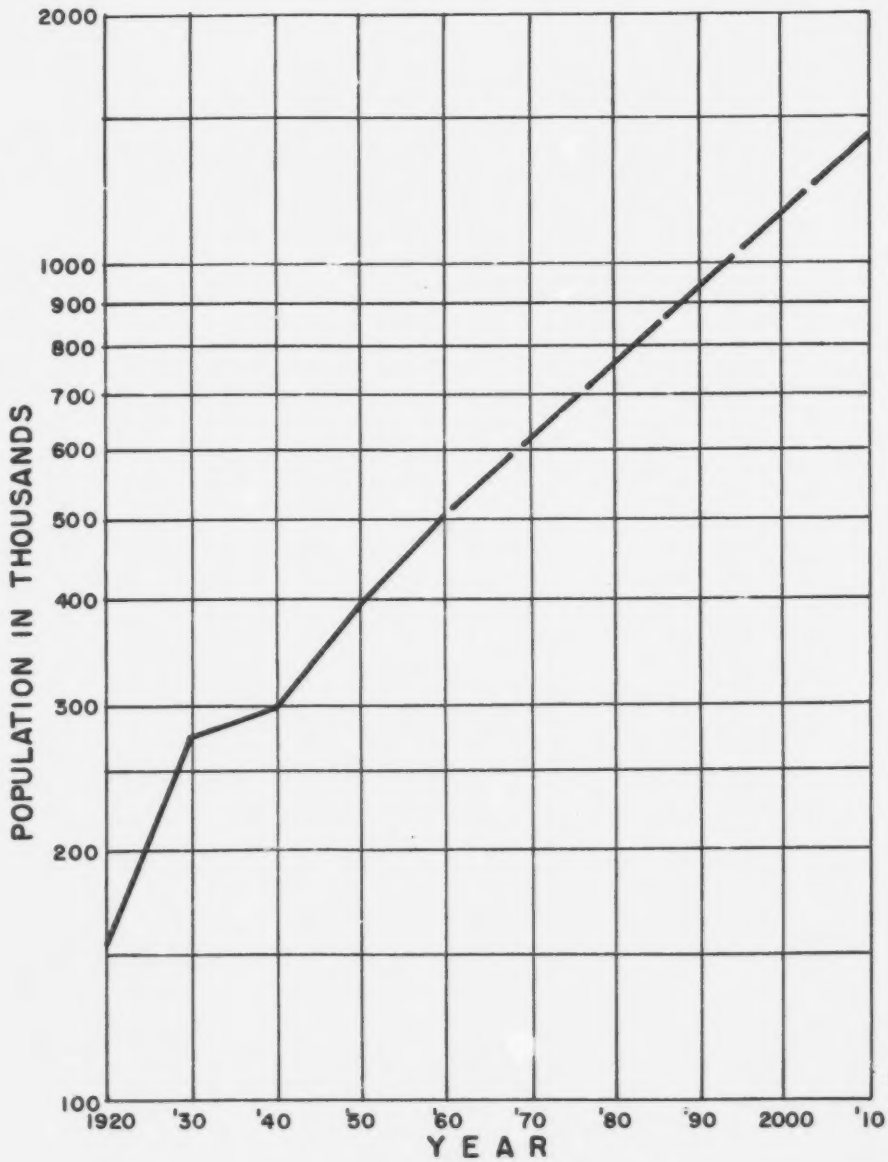
FIGURE 4

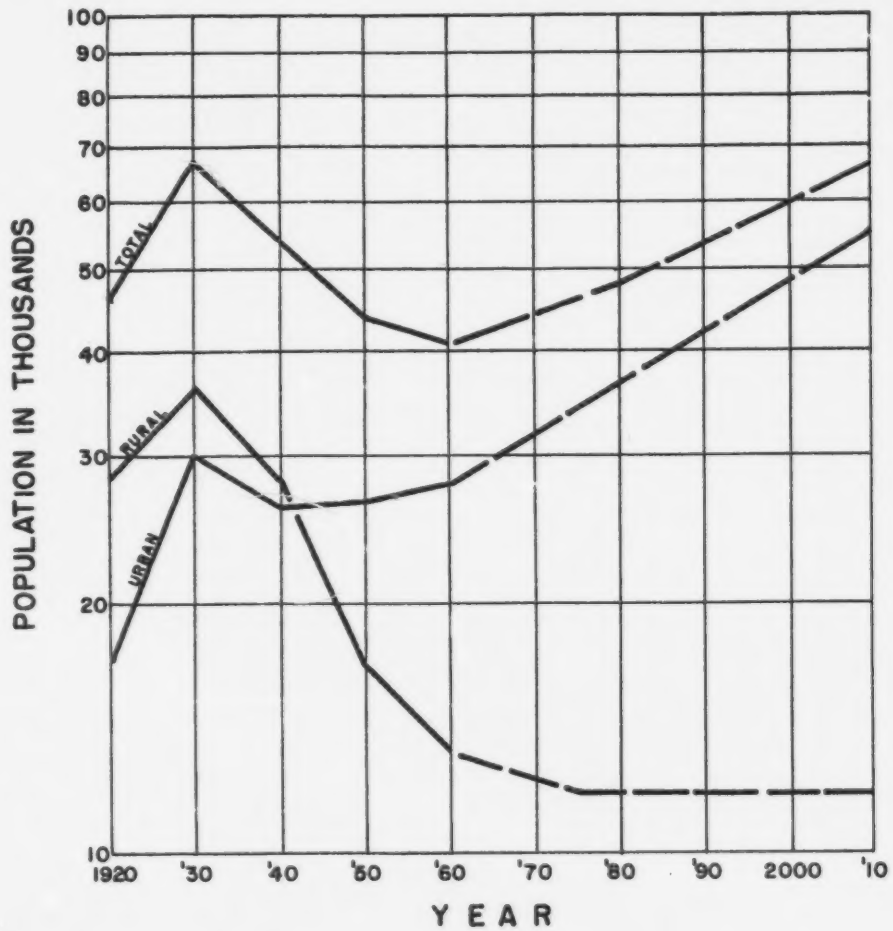


HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTION
SUB-AREA O-2

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 5



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTIONS
SUB-AREA O-3

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

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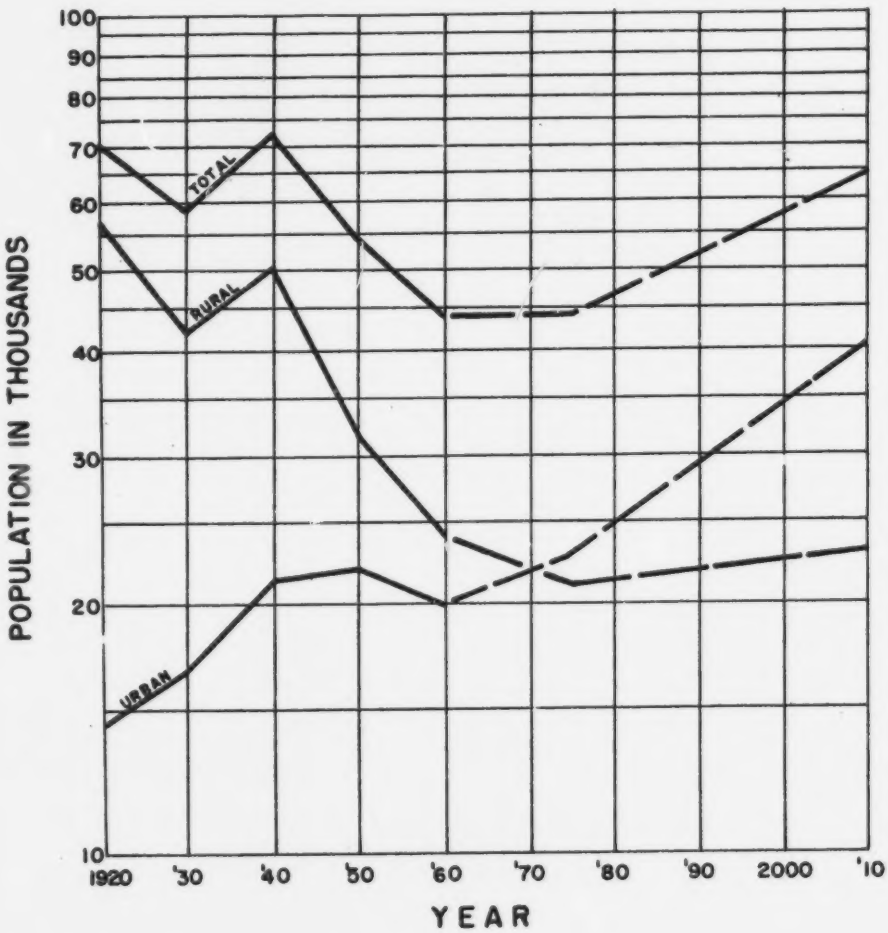
FIGURE 6



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTIONS
SUB-AREA 0-4

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

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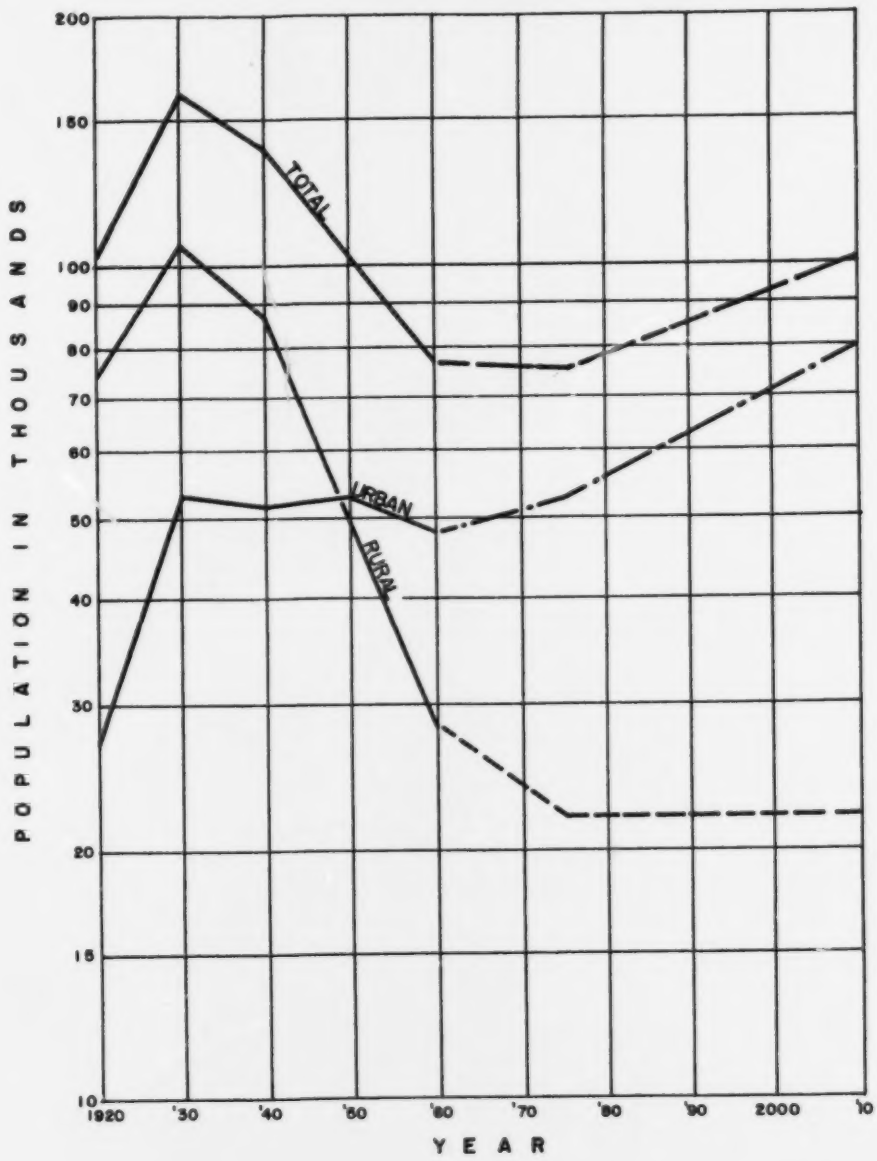
FIGURE 7

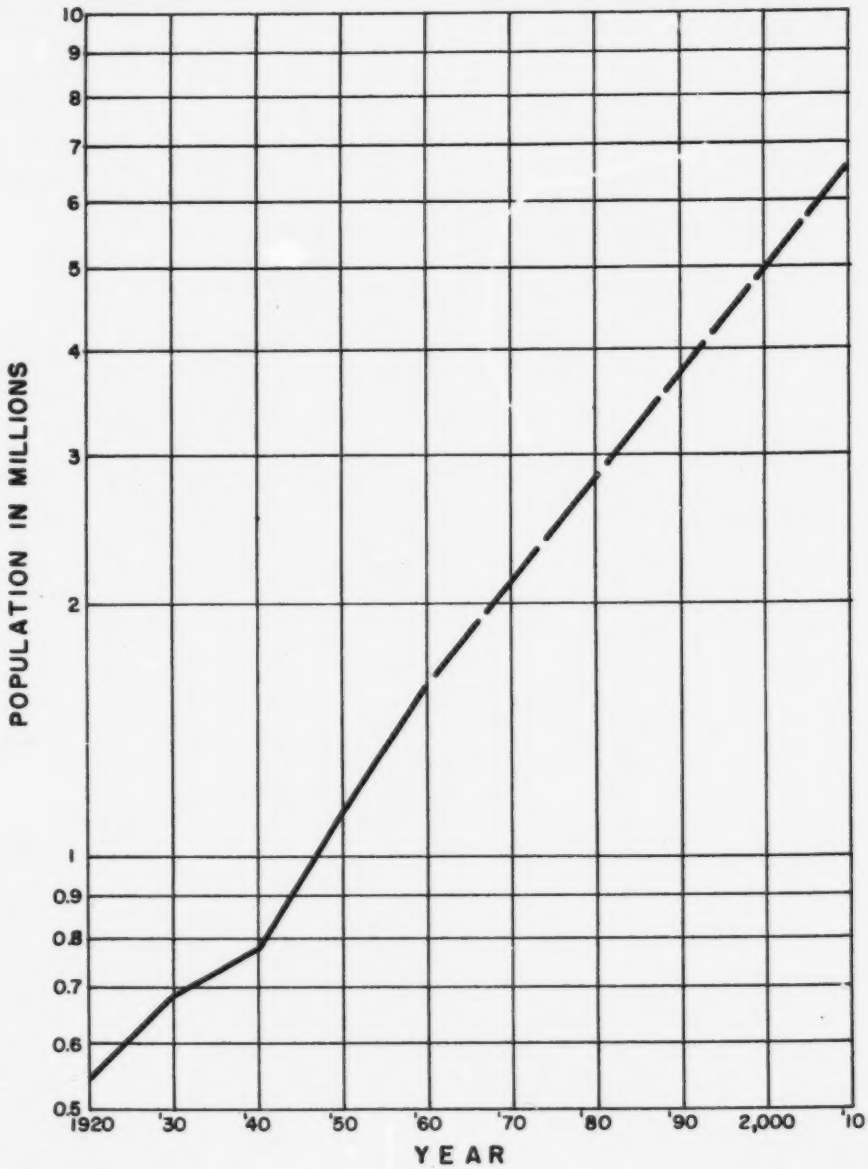


HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTIONS
SUB-AREA O-5

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 8



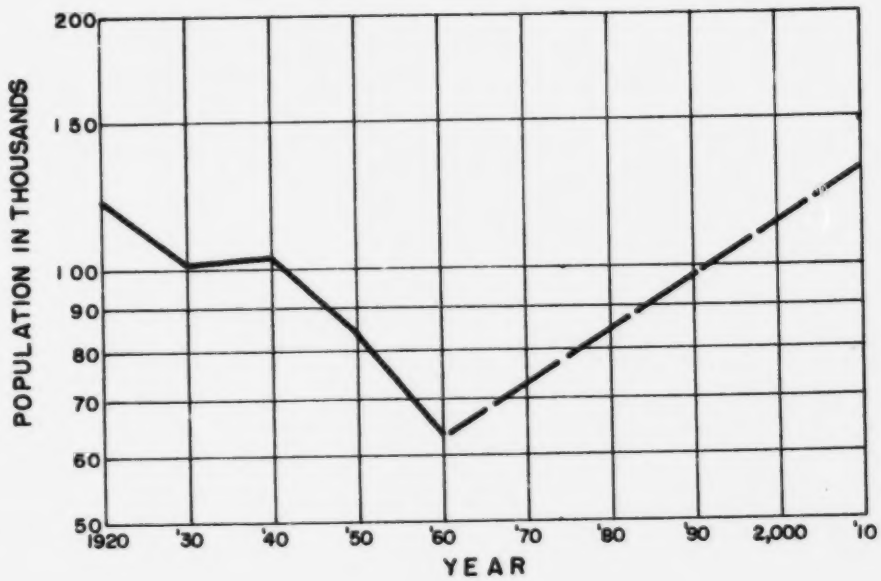
HUGO, TUSKAHOMA AND CLAYTON RESERVOIRS

POPULATION PROJECTION
SUB-AREA T-1

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

M.F.K.

FIGURE 9



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

POPULATION PROJECTION
SUB-AREA T-2

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

M.F.K.

FIGURE 10

VII. PROJECTED WATER DEMANDS

Future water requirements were projected by means of the procedures outlined in this chapter, and an inventory was made of existing and firmly committed* sources of supply which could be utilized in supplying all or a portion of these requirements. The difference between the projected requirements for each subarea, and the estimated yield of existing and firmly committed sources over the 50-year study period, is the total projected water demand which might be supplied from the project. These demands are summarized in Table 14.

Unit Municipal Water Use

A distinction was made between municipal and industrial water use and each was evaluated separately. Municipal water use, as defined for the purposes of this report, includes residential, public, commercial and those industrial uses which can reasonably be reflected in a per capita use figure. Projections of municipal water requirements were made by multiplying the projected municipal population by a unit use factor in gallons per capita per day (gpcd).

The determination of the per capita use factor is somewhat arbitrary. Data from individual municipalities in the study area were analyzed in an attempt to correlate per capita use with some indicator, such as population size group, personal income or climate, in order to project long-range per capita uses. Such analyses have thus far revealed little relationship between unit water use and any of these parameters. Therefore, for the purposes of this study, rather arbitrary values of per capita use, based primarily upon judgment, are adopted. These values appear to be consistent with those in use by water planning engineers in the study area, and it is felt that a sufficient margin of safety is incorporated to assure that future requirements will not be understated. The following Table 15 shows the per capita units used in making projections of municipal water requirements.

These unit uses represent the quantity of raw water which must be delivered to the treatment plant. They include distribution system losses, unaccounted-for water, treatment plant attenuation, and evaporation from receiving reservoirs. The unit uses do not include evaporation from source impoundments or losses in transit from the source to the receiving reservoir. Evaporation losses from source reservoirs are customarily subtracted from inflows in estimating the firm yield. Losses in transit are considered negligible if transmission is by pipe line; adjustments are made for losses if transmission is through open channels, whether natural or man-made. In the latter case, transmission loss, and all of the attendant costs, should be charged against the open channel in comparing it with a pipe line.

*Those sources which are not yet constructed but are firmly committed for construction in the near future.

Table 14

Projected Water Demands, By Subarea, 2010
(All figures are in mgd)

Subarea	Projected Water Requirements 2010 Municipal	Industrial	Total	Est. Yield Existing Sources	Projected Demand M & I	Year of Inadequacy of Exist. Sources	Power Generation Consumptive Use
0-1	5	23	28	3[a]	25	1964	10
0-2	276	160	436	139[b]	297	1980	85[c]
0-3	9	12	21	14	7	1985	Assigned to Capacity in Subareas 0-1 and 0-2
0-4	6.5	6.5	13	6[d]	7	1985	
0-5	13	10	23	12	11	1980	
T-1	1,273	229	1,502	548	954	1980	365[c]
T-2	e	e	e	e	None	e	e

a Includes Soil Conservation Service project which will provide municipal storage.

b Includes authorized but not constructed Little River Project.

c Not a potential demand on a study project.

d Includes Soil Conservation Service project which will provide municipal water supply storage for Coalgate.

e Previous Public Health Service study of this area indicates that arrangements have already been made either through municipal developments or by contract with the Corps of Engineers to provide for projected requirements.

Table 15

Projected Per Capita Water Requirements

Category in 2010	gpcd in 2010
Metropolitan centers with projected municipal populations of 500,000 and over	200
Cities with projected metropolitan populations of 50,000 to 500,000 and satellites of metropolitan centers	180
Cities with projected municipal populations of less than 50,000	150

Unit Industrial Water Use

Industrial water use is that volume of source water required by industrial plants for all purposes with the same qualifications as previously discussed for municipal water. As the term is used herein, industrial water is that water needed by industries having large demands, such as food processing plants, petroleum refineries, petrochemical plants and paper mills.* Such water demands may (or may not) be supplied from municipal systems. For the purposes of this report, the essential distinction is that their water use is not directly related to the population. Projections for this category of water use can be approached by two methods: (1) use per unit of product or (2) use per employee. The method employed in this study utilizes the latter method because of the nature of projections in the economic analysis. The projections in this study, therefore, are based upon an anticipated water use per employee, with a different factor for each major industrial classification.

Data on industrial water use in the study area were insufficient to develop satisfactory regional figures of per-employee water use for the several industrial categories considered in the economic analysis. Therefore, the figures employed in this study are based upon national average use data developed from the 1954 Census of Manufactures, "Industrial Water Use."44/ These data were arbitrarily modified in the case of the chemical and primary metals industries, to remove those components of the national average unit use which are not anticipated to develop in the study area, and adjusted for anticipated effects of increased labor productivity.

* Water requirements for thermal power production are projected separately at the end of this chapter. This separate evaluation is made since it is more feasible to project these requirements on a use per-kilowatt-hour basis, than on a per-employee basis.

Maximum unit water uses were projected on the basis of no recirculation; average unit use figures on the basis of average recirculation; and minimum unit uses on the basis of no recirculation of process and sanitary water but complete recirculation of cooling water, with a ten per cent make-up to cover evaporation and the necessary purges to maintain quality. The projected unit use to be applied was then determined for anticipated recirculation conditions within each subarea. Subareas in which water is assumed to be relatively plentiful at low cost were assumed to have an average or less than average per cent of recirculation; areas of relatively scarce, high-priced water were assumed to have almost maximum recirculation.

The procedure for projecting industrial water requirements was deviated from in the Texas portion of the study area because of a lack of time in which to develop complete economic projections. The methods employed for these subareas are discussed under the subarea in question. The procedure outlined above will be utilized for the final study.

Data available for this procedure were relatively scant and further investigation is being undertaken to refine the unit employee use figures as well as to determine the effect of water costs upon the amount of recirculation practiced. These refined data will be utilized in projections for the final comprehensive study.

Projected Subarea Demands

The remainder of this chapter presents water requirements, existing and firmly committed sources of supply, and water demands for each of several subareas. Specific points of water use are not determined since it is impossible to pinpoint the location of specific industries within the subareas. However, points of use are determined in each subarea for the purpose of making cost estimates for the value-of-storage determination.

Use by individual industrial categories and breakdowns of existing sources of supply are omitted from this interim report, but will be included in the comprehensive study report.

Subarea 0-1

The total projected water requirement for Subarea 0-1 is 28 mgd in the year 2010. The municipal component of this requirement is 5 mgd based upon a projected municipal population of 32,000 and a per capita use of 150 gpd. The industrial requirement is projected to be 23 mgd, of which 20 mgd is anticipated for use by the pulp and paper industry.

It is estimated that the present sources of supply will be capable of yielding some 3 mgd* in the year 2010,[46,47] indicating a future demand of 25 mgd beginning in the year 1964. Approximately 20 mgd of this demand, anticipated for the pulp and paper industry, will be supplied from relatively large impoundments with the industrial firm located near the impoundment.

The remainder of the industrial and all of the municipal demand would be spread over the remainder of the subarea. The municipalities of Hugo and Antlers are, however, the most logical points at which to place this demand for the purpose of estimating costs, since they are the most populous cities within the subarea.

Subarea O-2

The total projected water requirement for Subarea O-2, the major water demand area in the Oklahoma portion of the study area, is 436 mgd by the year 2010. The projected requirements are shown graphically in Figure 11. The municipal portion of the requirement is 276 mgd based upon a projected municipal population of 1,420,000 and a per capita use of 197 gpd. The per capita use was determined by estimating that portion of the projected municipal population falling into each of the three municipal groupings shown in Table 15, and determining a weighted average for the subarea.

The projected industrial requirement is 160 mgd in the year 2010 based upon the projected employment in the several industrial categories considered and the per employee water use for each category. In the case of this subarea, it was assumed that considerable recirculation, approaching a maximum, would be the rule by the year 2010 due to the anticipated high future cost of water after importation from considerable distances from the subarea.

The sources of supply available to meet the requirements of this subarea are estimated to be capable of supplying some 139 mgd in the year 2010, including the authorized, but not yet constructed Bureau of Reclamation project on Little River, which will supply water to the cities of Norman, Del City and Midwest City, and the Atoka Reservoir, for which transmission facilities will soon be constructed.[45,46,48,49,50] See Table 16. The indicated need, therefore, is 297 mgd with existing and firm sources being inadequate in the year 1980.

The projected demand in Subarea O-2 is anticipated to be centered at Oklahoma City and the point of use for estimating is a terminal storage reservoir just south of Tinker Air Force Base near Moore. See Figure 15.

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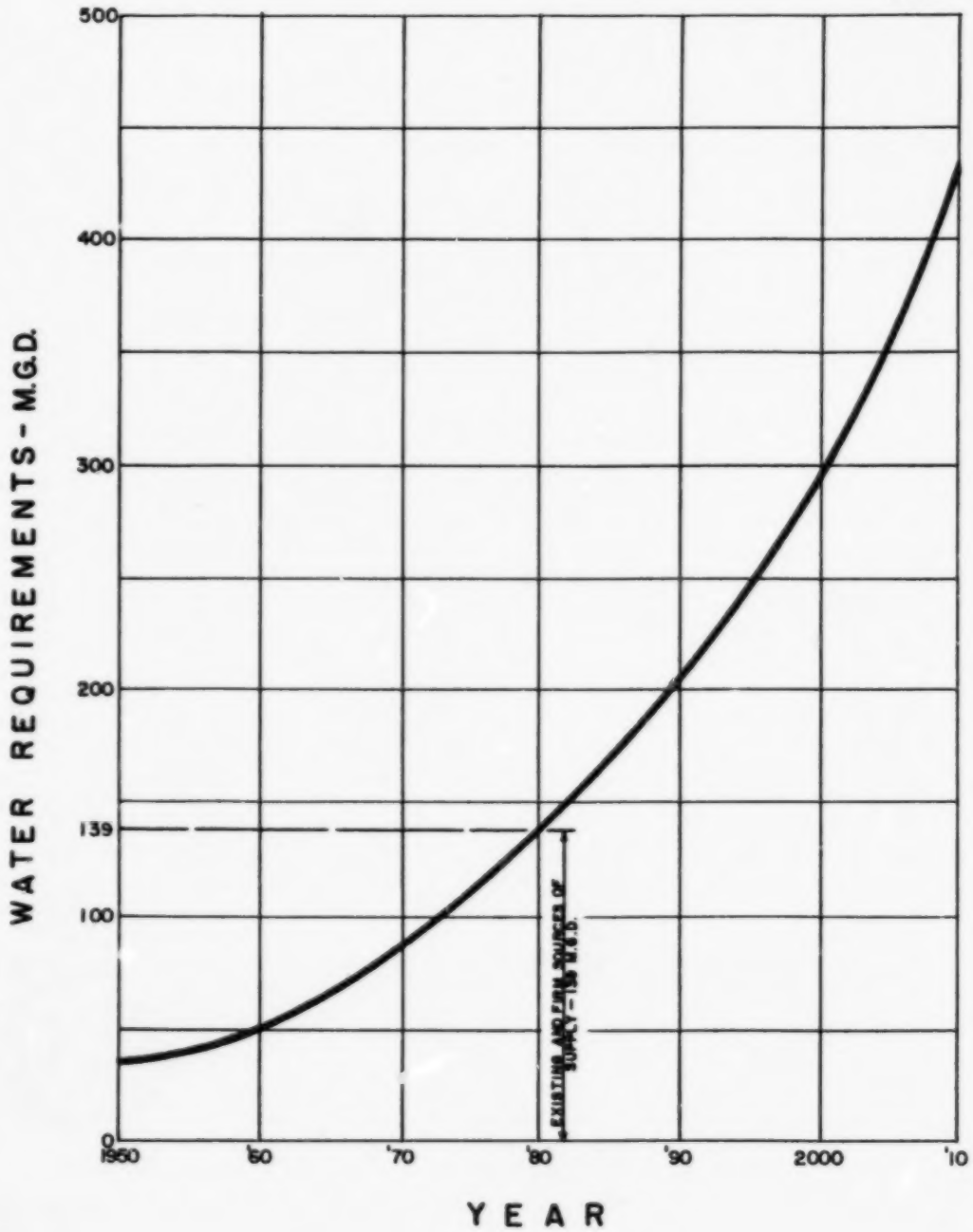
*Including the Soil Conservation Service project which is not yet constructed, but will supply water to the city of Wilburton.



HUGO, TUSKAHOMA, AND CLAYTON
RESERVOIRS

ESTIMATED WATER REQUIREMENTS
SUB-AREA O-2

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 11

Table 16

Existing and Firmly Committed Sources of Water Supply, Subarea 0-2

Source		Estimated 2010 Dependable Yield, mgd
Surface Water:		116
Lakes Hefner and Overholser	46	
Atoka Reservoir	45	
Authorized BuRec Little River Project	25	
Ground Water		23
Total		139

Subarea 0-3

Subarea 0-3 has a projected 2010 water requirement of 21 mgd. The municipal component is 9 mgd based upon a projected municipal population of 60,000 and a per capita use of 150 gpd. The industrial component is projected to be 12 mgd.

Existing sources of supply are estimated to be capable of yielding 14 mgd in the year 2010, indicating a future demand of 7 mgd, with the existing sources becoming inadequate in the year 1985.[46]

It is anticipated that the major demand will emanate from the vicinity of Shawnee, and the entire demand is placed at this point of use for making cost estimates.

Subarea 0-4

The total projected water requirement for Subarea 0-4 is 13 mgd by the year 2010. The municipal portion of this requirement is 6.5 mgd based upon a projected municipal population of 43,500 and a per capita use of 150 gpd. The industrial use is projected also to be 6.5 mgd by the year 2010.

Existing and firm sources of supply are estimated to be capable of providing 6 mgd in the year 2010 including the proposed Soil Conservation Service project which will provide municipal storage for the city of Coalgate.[46,51] The projected demand for this subarea is indicated to be 7 mgd by the year 2010, beginning in approximately 1985.

The major area of anticipated development in the subarea is in the vicinity of Ada. Therefore, Ada is the assumed point of use for cost estimating purposes and the entire demand is assigned to this point.

Subarea 0-5

The total projected water requirement for Subarea 0-5 is 23 mgd in the year 2010. The municipal requirement is projected to be 13 mgd based upon a projected municipal population of 85,000 and a per capita use of 150 gpd. The industrial component of this requirement is projected to be 10 mgd.

It is estimated that existing sources of supply within the subarea will be capable of supplying 15 mgd in the year 2010.46/ However, since major growth is anticipated to occur in the Seminole and McAlester areas, and some of the available sources capable of supplying an excess over current requirements are not located advantageously in relation to these cities, the demand is projected at 11 mgd rather than the apparent 8 mgd. For the purpose of cost estimates, it is assumed that 4 mgd of this demand will be concentrated at Seminole and 7 mgd at McAlester.

Subarea T-1

The water requirements for Subarea T-1 were projected somewhat differently from those for the preceding five subareas. Projections of municipal population were available but complete economic analyses for this subarea were not obtainable at the time the water requirements were projected; therefore, municipal requirements were projected on the same basis as that employed in Subarea 0-2, that is, the projected municipal population was distributed into population groupings corresponding to the per capita use, as shown in Table 15, to obtain a weighted average per capita use for the entire subarea. The municipal component of the requirement is projected to be 1,273 mgd in the year 2010 based upon a projected municipal population of 6,530,000 and a per capita use of 195 mgd.

The projected industrial requirements were estimated on the basis of a per capita requirement rather than a per employee requirement. This approach is felt to be valid for this subarea and should provide a projected requirement which will not vary significantly from that which will be obtained for the comprehensive study by the per-employee method. The validity of the approach is attributable to the diversified industrial structure of the subarea which tends to even out extremes of water use among industrial categories which would not be the case for a less diverse area. In addition, large water-using firms individually are a relatively small portion of total water use in the subarea and the introduction of even several such firms would not drastically change the overall balance between segments of water use.

The per capita figure was determined by investigating the present relationship of industrial to total municipal and industrial use. Industrial use is equal to about 17 per cent of this total.

It is felt that the per cent relationship would decrease in the future as increasing water scarcity and increasing costs prompted more recirculation and other water conserving measures among industrial firms. Industrial use was therefore estimated as 15 per cent of total water use in 2010 or 35 gpcd. Projected industrial use is 229 mgd by the year 2010.

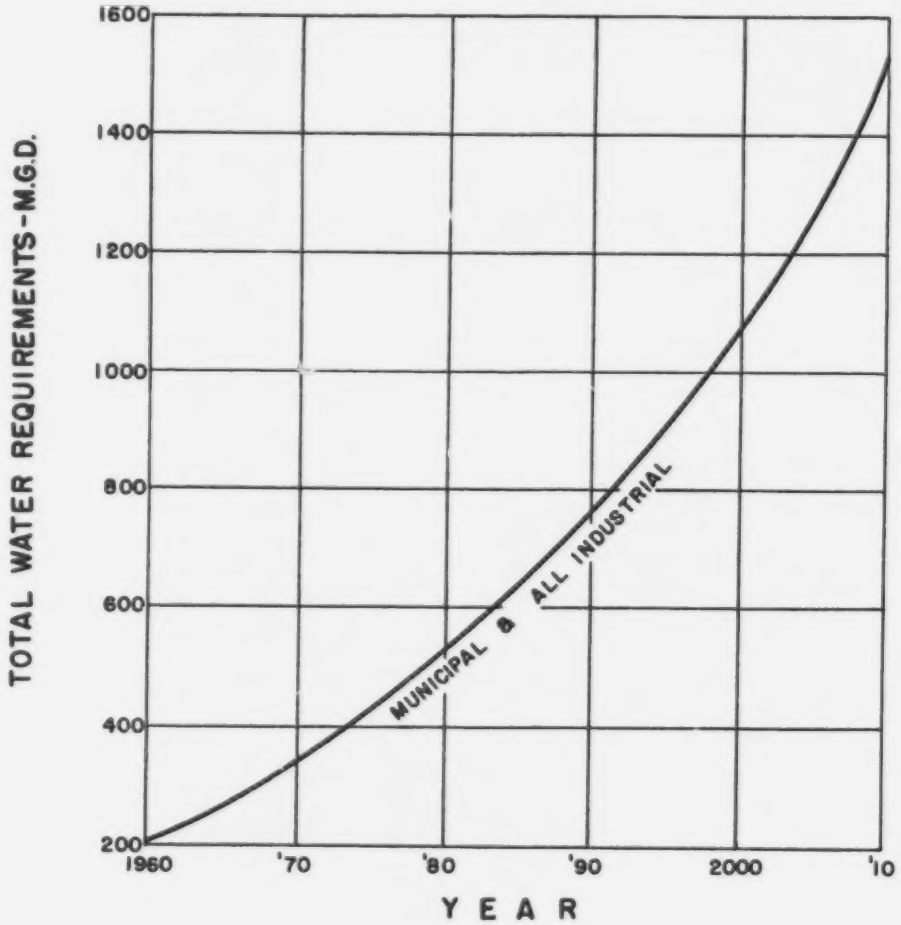
The total projected water requirement for Subarea T-1 is 1502 mgd by the year 2010, as shown on Figure 12.

Existing and firm sources of supply are estimated to be capable of supplying 548 mgd in the year 2010.45,46,52/ See Table 17. This includes the not yet constructed Cedar Creek project which has been authorized and is being financed by the city of Fort Worth. The projected demand for this subarea for municipal and industrial purposes is 954 mgd in the year 2010. However, as discussed in "Alternative Water Supply Plans," much of this demand can be met by low-quality sources such as return flows from municipal uses. The major demands will occur in Dallas and Tarrant Counties; therefore, the point of delivery for estimating purposes is taken to be terminal storage in the Grapevine Reservoir, just north of the city of Grapevine. See Figure 16.

Table 17

Existing and Firmly Committed Sources of Water Supply, Subarea T-1

Source	Estimated 2010 Dependable Yield, mgd	
Surface Water:		528
Amon Carter Reservoir	1	
West Fork System	45	
Benbrook Reservoir	5	
Lake Arlington	2	
Lewisville Reservoir	93	
Grapevine Reservoir	14	
Lavon Reservoir	44	
Iron Bridge Reservoir	146	
Lake Weatherford	1	
Waxahachie Reservoir	3	
Cedar Creek Reservoir	174	
Ground Water		20
Total		548



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

ESTIMATED WATER REQUIREMENTS
SUB-AREA T-1

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

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FIGURE 12

Subarea T-2

Again a departure from the standard techniques of the comprehensive study has been made because of the absence of complete economic analysis for Subarea T-2 at this time. This subarea has been investigated in a previous study by the Public Health Service[53] and the projected water demands were taken directly from that report. For the comprehensive study, a restudy of this subarea will be made; however, the data presented are considered sufficiently accurate for this report since the magnitude of the demands are small in relation to total demands in the Texas portion of the study area.

Future demands for Subarea T-2 are projected to be 28 mgd in the year 2010. The city of Bonham accounts for 3 mgd of this demand and is presently developing a municipal source to provide for this demand. The remaining 25 mgd is anticipated to occur in the vicinity of Paris. City officials have expressed an interest in contracting with the Corps of Engineers to obtain storage in the Sanders Project, near Paris, capable of supplying 55 mgd, which is ample to provide for the future demand in this area. This project is being studied by the Corps of Engineers. It appears, therefore, at this time that there is no unsatisfied municipal and industrial demand in Subarea T-2.

Water Requirements for Power Production

Water requirements for production of thermal electric power were evaluated separately from municipal and industrial needs. The electric power industry as a whole is the largest user of water in the United States. However, the major portion of the water is returned to the stream relatively undiminished in quantity and quality. In this analysis only those uses of the power industry which result in a consumption of water are considered.

The amount of water necessary on a consumptive basis for power production was projected on the basis of a per capita kilowatt hour consumption and a unit consumptive use of water per kilowatt hour. Because of the wide range of estimates in both of these variables, the following pattern was used in projections:

1. High median and low total kilowatt hour consumptions were projected on the basis of Federal Power Commission, and Edison Electric Institute projection for the years 1975 and 2000.[54]

2. Unit consumption figures were developed on the basis of existing averages for thermal electric plants and considered as the upper limit of water use per kilowatt hour. A lower limit was developed based upon information developed by several southwestern power

companies for this study and a median value was determined between these lower and upper limits, based primarily upon judgment as to the average use in the sum total of plants, both old and new.55/

3. Projections were made by multiplying the high projected kwhr consumption by the high projected water use per kwhr; the median by the median and the low by the low.

4. A value was selected on the basis of anticipated development in the area, the relative availability of cheap water and the anticipated efficiencies of power plants in the area. In general, the value selected corresponded most nearly to the median value, judged in the light of the low and high projections, and projections by the power companies and others.

5. Logical means of supplying this requirement from existing sources were then studied to determine if in fact this requirement was a demand which would logically be supplied from the study projects. In many cases, the return sewage flows could be of sufficient volume discharged in single flows to provide the cooling water for the consumptive power uses.

On the following pages are developed the projected consumptive water demands for electric power production.

Subarea 0-1

The projected consumptive water use for power production is 4 mgd by the year 2010. In addition, there is a projected requirement of 6 mgd assigned from Subareas 0-3, 0-4, and 0-5 as discussed under "Subareas 0-3, 0-4, and 0-5" which follows, making a total demand of 10 mgd. Since this is an area of relatively abundant water, with the municipal and most of the industrial waste effluents spread over the entire area, it appears that these consumptive uses will be met from development of new sources of supply rather than reclaimed water. These demands, therefore, comprise a potential demand on the study projects.

Subarea 0-2

The projected consumptive water use for Subarea 0-2 for electric power production is 76 mgd by the year 2010. In addition, there is a projected requirement of 9 mgd assigned from Subareas 0-3, 0-4,

and 0-5 for a total of 85 mgd. Since this area will be transporting water many miles for the previously determined municipal and industrial water uses, it is presumed that the price of new water will be excessive for use by the power industry and that they will turn to reclaimed effluent to meet their needs.55/

Based upon the projected water uses for municipal and industrial uses, the return flows by the year 2010 are estimated to be a minimum of 200 mgd. This is based upon a return flow factor of 50 per cent. It is seen that the return flows produced should be more than sufficient to meet the projected demands; therefore, it is not anticipated that the power production in Subarea 0-2 will have a demand for storage in the Corps of Engineers projects.

Subareas 0-3, 0-4, and 0-5

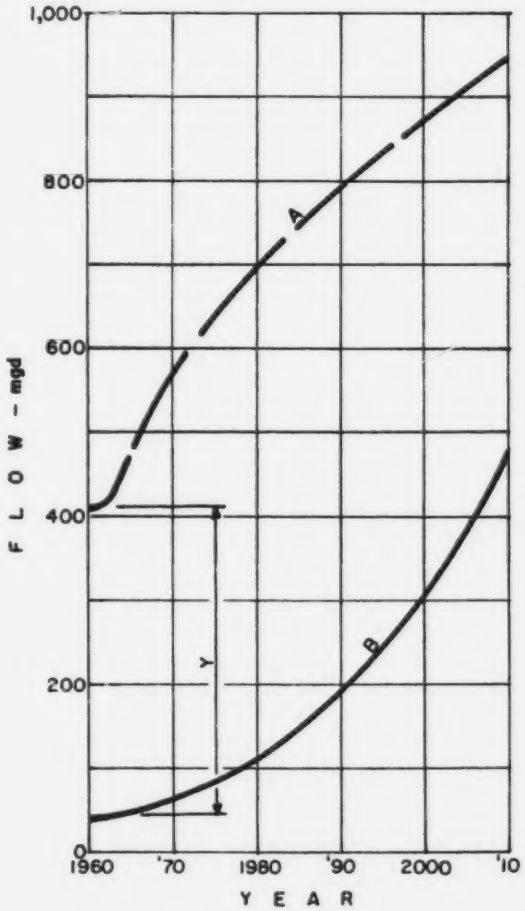
Subareas 0-3, 0-4, and 0-5 do not have a high enough projected power demand to consider the location of generating capacity within their boundaries. Subarea 0-2 will require large blocks of power in the future and it would appear to be a logical choice of location of such facilities. It is assumed that power from this subarea will be exported to serve the western portion of the three subarea group.

Subarea 0-1 has readily available low-cost water and is mentioned as an area with generating requirements by the Public Service Company of Oklahoma for their future generation. The water requirements for the eastern portion of the three subarea groups are therefore assigned to Subarea 0-1.

The total projected water requirements for power production are 15 mgd of which 9 mgd are assigned arbitrarily to Subarea 0-2 and 6 mgd to Subarea 0-1.

Subarea T-1

The projected water requirement for power production to supply the demands of Subarea T-1 is 365 mgd in the year 2010. As anticipated growth occurs, there will be, within the Upper Trinity Basin, several hundred million gallons of water per day which could be impounded for some industrial and most of the thermal electric requirements although it is unsuitable for municipal use since it consists chiefly of return sewage flows.56,57/ Based upon the projected municipal requirement in 2010, there appears to be sufficient water to provide for the overall eight-tenths of the combined industrial and thermal electric requirement for which it is considered suitable. This is shown graphically in Figure 13. It is not anticipated that there will be any demand added to that already determined for Subarea T-1 for thermal electric water requirements. Further mention of the means of meeting this demand is made in the section entitled "Alternative Water Supply Plans."



LEGEND

A. TOTAL RETURN FLOWS, EXISTING SOURCES AND TENNESEE COLONY RESERVOIR.

B. PROJECTED REQUIREMENTS, LOW QUALITY INDUSTRIAL WATER (INCLUDING THERMAL ELECTRIC POWER GENERATION)

Y. TENNESEE COLONY RESERVOIR, 370 MGD (INCLUDING 100 MGD RETURN FLOW)

HUGO, TUSKAHOMA AND CLAYTON RESERVOIRS

LOW QUALITY WATER REQUIREMENTS SUB-AREA T-1

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

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FIGURE 13

Subarea T-2

Projections of the future water requirement for power production were not made for this subarea since total water already planned for the subarea, primarily in the Sanders Creek project, will be sufficient to meet the requirements.

VIII. ALTERNATIVE WATER SUPPLY PLANS

This section presents the alternative plans considered most feasible to supply the projected water demands of the several subareas. Plans are presented for each subarea having a water demand: (1) a plan which is the most logical means of supplying the demand from storage in the proposed Corps of Engineers study project, and; (2) the most feasible plan or plans which an area might be expected to follow in the absence of the proposed study project. These plans are compared as to point of use and water quality; source development costs are considered for the latter plans. The plans considered most feasible are shown in Table 18 along with estimated costs.

Capital costs of alternative plans are converted to equivalent annual costs over the assumed economic life of a project (50 years), using a non-Federal interest rate of four per cent. All costs are presented as 1965 present worth to permit comparison of plans on a common base, as well as to reflect the fact that many projects will not be needed until many years in the future. The year 1965 was chosen as the base year since this is the earliest practical date by which the multipurpose projects could be completed and in use. In addition, the use of present worth indicates the most feasible development of the projects to obtain an economic utilization of resources.

The costs used in computing the various total costs of alternative plans are presented in Exhibit B in the Appendix. The location of alternatives is shown on Figures 15 and 16.

For the purpose of eliminating needless calculations, it is assumed that areas of small demand lying at some distance from the study reservoirs cannot afford the costs of transmission from the study projects by themselves and that they will not be a demand on the project unless it proves economically feasible for the major demand area, i.e., Oklahoma City metropolitan area, to transport the water from the study projects. In such case, the intermediate small-demand area will be evaluated as being serviced from the transmission main to this demand area. This is applicable to Subareas 0-3, 0-4, and 0-5.

Subarea 0-1

The total water demand of Subarea 0-1 by the year 2010 is 25 mgd for municipal and industrial purposes and 10 mgd for power as projected in the section of this report entitled "Projected Water Demands." As previously mentioned some 20 mgd is projected for the pulp and paper industry, with the municipal and the remainder of industrial needs spread more or less evenly throughout the subarea. For the purposes of estimating, this portion of total use is concentrated at Hugo and Antlers. Since they could most logically be served from the proposed Hugo Reservoir, the entire demand for the subarea is assigned to this reservoir.

Table 18

Estimated Cost of Plans to Supply Projected Water Demands
(All Costs Expressed in 1965 Present Worth)

	Subarea 0-1		Subarea 0-2					
			Multipurpose Trans. Only		Single Purpose		Southern System	
	Hugo Multi-purpose Trans. Only (1)	Local Alterna-tive (2)	Clayton (3)	Tuskahoma (4)	Clayton (5)	Tuskahoma (6)	Alternative to Clayton (7)	Alternative to Tuskahoma (8)
Year of Need	1964	1964	1980	1980	1980	1980	1980	1980
Demand, mgd	35	35	160	200	160	200	160	200
Alternative to: (By column nos.)	---	(1)	---	---	(3)	(4)	(3)	(4)
Total Capital Expenditures and Interest ($1,000)	(No) (trans-) (mission) (adjust-) (ment) (needed)	$2,855	$97,600	$117,500	$107,000	$127,410	$123,350	$131,500
Total Operation & Maintenance Expenditures (For 50 years from date of first use)($1,000)		536	35,850	40,700	36,850	41,760	33,600	38,450
Total ($1,000)		$3,391	$133,450	$158,200	$143,850	$169,170	$156,950	$169,950
Most Economical Alternative to Multi-purpose Project (By column nos.)	(2)	---	(5)	(6)	---	---	---	---

The plan for supplying the future needs of this subarea from the Corps of Engineers project assumes the location of pulp and paper, and thermal electric power plants on the Hugo Reservoir within sufficient distance to make the costs of transmission equal to the costs if the industry constructed its own reservoir. The cost of transmission to the point of use is therefore irrelevant to the determination of value of storage in the project and is disregarded.

The alternative plan is based upon the development of sources of supply yielding sufficient water to meet the projected demands on an individual basis, that is, each municipality or industry would develop its own source of supply. Ground water is not considered as an alternative source of supply although it is presently a source for several municipalities. Very few studies of ground water availability have been made in this subarea. There are no large aquifers known to exist. According to geology, most of the rocks are relatively dense and would not be likely to yield large supplies.58/

Surface water is readily available. There are several reservoir sites capable of yielding large quantities of water which are presently undeveloped. The projected demand, however, does not warrant construction of the large reservoirs. Due to the type of terrain found in Subarea 0-1 - mountainous, with many small streams, it is felt that there would be many small-yield sites which could be developed. Therefore, rather than attempting to pinpoint exact sites, it is assumed that individual industries and municipalities could develop sufficient water in close proximity to the point of use. Estimated costs of development of sites in this subarea range from $30 per acre-foot of storage for a small reservoir in Latimer County, to $40 per acre-foot for some of the large reservoirs. The average cost of developing surface water sites is taken to be $37 per acre-foot of storage. Based upon the projected demand of 35 mgd and an average of 1,300 acre-feet of storage per mgd yield, to provide allowance for sedimentation and a safety factor, the average amortized cost of storage is estimated to have a 1965 present worth of $3,391,000 including operation and maintenance of the reservoir.

In the case of water supplies for the pulp and paper and thermal power industries, the estimated capital, and annual operation and maintenance costs for transmission are assumed to be equal, as previously mentioned, whether water is obtained from the proposed Hugo Reservoir or from privately developed reservoirs. In the case of municipal water demand and the remainder of the industrial demand, transmission to the point of use must be considered. Hugo and Antlers, assumed as the points of water use for estimating purposes, lie only a few miles from the proposed Hugo Reservoir and could probably not develop a source of their own any closer to the city. Therefore, it is assumed that equal transmission costs to the point of use will be incurred under both of the alternatives.

The quality of water under both of the alternative plans is approximately equal since alternatives would be located on tributaries of the Kiamichi River watershed, while the Hugo project would be on the main stem. Treatment costs would therefore be equal for both plans.

In summary, the cost of obtaining water from the proposed Hugo Reservoir, excluding the cost of storage, is estimated to be equal to the cost of obtaining water by the alternative plan, excluding the cost of storage.

Subarea 0-2

The total projected water demand for municipal and industrial uses in Subarea 0-2 is 297 mgd by the year 2010. This demand would be sufficient to call for the total yield of either Clayton or Tuskahoma and a major portion of the yield from the other. Therefore, a plan for supplying these needs from both Clayton and Tuskahoma was developed as well as an alternative plan to each of these proposed projects. The demand was not considered as a potential demand on Hugo Reservoir since Tuskahoma and Clayton are some 200 feet higher in elevation than Hugo. Oklahoma City, the major demand center in Subarea 0-2, has stated an interest in Clayton and Tuskahoma, but not in Hugo.

In determining alternative plans, an investigation of possible sources showed few within the subarea itself. Several rivers within or close by the subarea, such as the South Canadian and Cimmaron have sufficiently large flows to be considered as alternatives. However, since these waters are high in dissolved minerals, they were dropped from further consideration.

Ground water is available in the subarea from the Garber and Wellington formation. Many small municipalities and private industries utilize water from this formation as their present source of supply. Existing wells, properly spaced, show little decline in water levels. In many portions of the area, however, particularly near Norman, insufficient spacing and overpumping of wells have created problems in obtaining sufficient water.[45,46,58]

The Guernsey Engineering Company recently made a study of ground water in this area, and among their conclusions stated that ground water depletion is not yet serious except for local conditions at Norman, and that withdrawals, at substantially higher rates than the present pumpage, could be maintained for a comparatively indefinite length of time, provided that the withdrawals are spread over a large enough area. The estimated maximum recharge rate is 24,135 acre-feet per year although the high possibility of error is stressed. Current withdrawals, including Oklahoma City, Norman, and points east of a line through these cities are estimated at 17,000

acre-feet. The estimated cost of developing sufficient wells to supply 1980 needs on a permanent basis for Del City, Norman, and Midwest City is approximately 19 cents per 1,000 gallons. The pumpage would also be greater than estimated recharge.59/

It appears that ground water resources in this area, while still not completely developed, lack sufficient reserve and are too expensive to be considered as an alternative source. Existing ground water sources are considered as lasting through the year 2010. However, it was decided to leave the remaining undeveloped yield, uncertain as it is, as a safety factor for use by the rural population and those municipalities and industries currently utilizing ground water.

The most likely alternative sources of supply are outlined in the "Long-Range Water Supply Study for Oklahoma City." 49/ These sources are surface water impoundments in southeastern Oklahoma and include the McGee Creek, Ten Mile Creek, and Buck Creek dam sites as well as a low dam on the Kiamichi River.49,50,60/ See Figure 15.

Other possible alternatives considered are single-purpose reservoirs at the Clayton and Tuskahoma sites.

Plan A, which calls for supplying demands from Clayton multipurpose reservoir, consists of a 90-inch pipe line from Clayton to the terminal storage reservoir south of Tinker Air Force Base. The 1965 present worth of transmission only, for this plan, is estimated to be $133,450,000, including amortized capital expenditures, interest, and operation and maintenance over the period 1980 to 2030, with facilities designed for a capacity of 160 mgd.

Plan B, which utilizes water supply storage in the proposed Tuskahoma Reservoir, consists of a 96-inch pipe line from Tuskahoma to the terminal storage. The 1965 present worth of transmission only is estimated to be $158,200,000, including amortization of and interest on capital expenditures, and annual operation and maintenance costs over the period 1980 to 2030 with facilities designed for 200 mgd capacity.

Plan C consists of the same transmission facilities as Plan A, but includes the development of a single-purpose water supply reservoir at the Clayton site. The 1965 present worth of developing this source plus transmission costs is estimated to be $143,850,000, including amortization and interest on the capital expenditures and annual operation and maintenance of the reservoir and transmission facilities for the same period as considered in Plan A.

Plan D consists of the same transmission facilities as developed for the Tuskahoma multipurpose site, but includes the development of a single-purpose water supply reservoir at the same site.

The 1965 present worth of developing this alternative plan is $169,170,000, including amortization and interest, and annual operating and maintenance costs.

Plan E develops the alternative sources of supply proposed in the long-range water supply plan for Oklahoma City. The overall plan was laid out and the costs of that portion which would be needed to yield 160 mgd, the yield of the proposed Clayton Reservoir, was determined in order to provide an alternative plan to the Clayton project. The order of total development is as follows:

Project	Year Needed	Yield, mgd
McGee Creek 72" Pipe Line from McGee Creek to Terminal	1980	50
Buck Creek Reservoir and Low Dam on Kiamichi River and Pipe Line from Buck Creek to McGee Creek	1988	115
Ten Mile Creek Reservoir	2000	115

The low dam on the Kiamichi River is capable of yielding some 100 mgd at a minimum. Excess storage in relation to runoff is provided in the Buck Creek and Ten Mile Creek projects to provide storage for water pumped from the Kiamichi during periods of high flow in order to carry over the critical periods. It is assumed that the total capital expenditure for the Kiamichi Low Dam is made at the time of constructing Buck Creek. The yield, however, is split equally between the Buck Creek and the Ten Mile Creek projects since they both provide approximately the same storage volume and the same yield. The portion of this alternative plan capable of yielding 160 mgd has an estimated cost of $156,950,000, expressed as 1965 present worth, including, capital expenditures, interest, and annual operation and maintenance for the period 1980 to 2030.

Plan F utilizes the same sources as Plan E. However, further development of the total available sources is undertaken to provide a yield of 200 mgd which is the yield of the proposed Tuskahoma project. The 1965 present worth of developing Plan F is $169,170,000, including capital expenditures, interest, and annual operation and maintenance costs for the period 1980 to 2030.

Transmission cost differentials for the various plans have been taken into consideration in that the cost of transmission was estimated as part of the cost for each plan. The water quality is anticipated to be sufficiently similar, regardless of the plan considered, to render the treatment differential negligible if not nonexistent. The differences between the costs presented are, therefore, the total cost differentials between alternative plans.

Intermediate Subareas

As was previously mentioned, the water demand which may be economically provided by storage in the proposed reservoirs would be determined by the cost of transmission through a line serving the major demand of Subarea 0-2. Since it appears that it is economically feasible for Subarea 0-2 to obtain water from either Clayton or Tuskahoma multipurpose projects (the cost of transmission only being less than the total cost of the most economical alterative plan), the means of supplying the demands of the three intervening subareas are investigated to determine whether they might be potential demands on the study projects.

The cost of main-line transmission to the Oklahoma City terminal in Subarea 0-2 is 6.2 cents per 1,000 gallons from Clayton or Tuskahoma. Assuming that the intervening municipalities paid for water purchased from the main line at a uniform gate rate (the same cost as that paid to move water to the end of the transmission line), the cost of transmission in cents per 1,000 gallons above would be equal, in each case, to the cost of water to the intermediate user at the point of takeoff, less his proportional share of the storage costs. In addition, the intermediate users would be obliged to construct and maintain a lateral main from the point of takeoff to the point of use. The cost of this lateral would vary with demand and distance from the main line. It is assumed that energy costs are included in the cost of water at the point of takeoff under the uniform gate rate, since sufficient head appears to be available at the point of takeoff to move the water to the point of use. Allowable head losses in the laterals are limited to 100 feet to assure this condition.

The cost of developing local alternative sources of supply is computed and compared to the above cost of transmission from the proposed multipurpose project. If the cost of transmission is less than the cost of developing a local alternative, then the demand could feasibly be supplied from the proposed project; if transmission is higher than the total cost of developing a local alternative, then it is considered economically infeasible for the subarea to obtain water from storage in the proposed multipurpose project and the demand is not considered to be a potential demand on a study project.

In all cases the present worth of transmission only from the study projects is more than the present worth of developing local alternative sources of supply, as shown in Table 19. Therefore, it appears that storage in the Clayton and Tuskahoma projects is infeasible for these intermediate subareas and their demand is not included in the value of storage determination.

Table 19

Economic Feasibility of Utilizing Storage in Clayton and Tuskahoma Reservoirs to Supply Demands of Subareas 0-3, 0-4, and 0-5
(All Costs Expressed as 1965 Present Worth)

Sub-area	Point of Use a/	2010 Demand (mgd)	Estimated Cost (¢/1000 gal) From Multi-purpose Clayton or Tuskahoma b/	Local Alternative c/	Is Use From Multipurpose Economically Feasible?
0-3	Shawnee	7	6.2	3.0	No
0-4	Ada	7	9.1	3.3	No
0-5	Seminole	4	6.6	3.6	No
	McAlester	7	7.0	1.2	No

a Assumed point of use within subarea for purposes of determining value of storage.

b Cost of transmission only.

c Cost of alternative includes source development as well as transmission.

Subarea 0-3

The total demand of this subarea is estimated to be 7 mgd for municipal and industrial uses by the year 2010. This need is assumed to be concentrated in the vicinity of Shawnee.

The cost of transmission at a uniform gate rate from the Clayton Subarea 0-2 terminal is estimated at 5.92 cents per 1,000 gallons. In addition to this rate there would be the cost of transmission from the major transmission line to the assumed point of use. This is a distance of four miles for which a 20" pipe line is computed as the economical size. Sufficient energy will be available at the point of takeoff from the large main to move the water to the point of use and the costs of this energy are already included in the cost of water at the takeoff.

The total cost of water delivered to the point of use, therefore, is equal to the uniform gate rate charge plus the amortized capital cost and annual maintenance charges of the transmission facilities from the point of takeoff to the point of use. The cost of transmission only from the Corps of Engineers project to the point of use in Subarea 0-3 is estimated to have a 1965 present worth of 6.2 cents per 1,000 gallons over the study period.

The alternative source of supply for this subarea is a reservoir site on Pecan Creek,61/ capable of yielding 7 mgd which would be needed about 1985. The cost of developing this alternative, including source development and transmission to the point of use, interest and annual operation and maintenance would have a 1965 present worth of 3.0 cents per 1,000 gallons over the study period.

Since the present worth of transmission only, from the study reservoirs Clayton and Tuskahoma, is more than the present worth of the alternative plan, including source development, it appears that the use of storage in the study projects is not economically justified. Therefore, the potential use of water from Tuskahoma or Clayton multipurpose reservoirs in Subarea 0-3 is not in fact a demand on the projects and is therefore not considered further.

Subarea 0-4

The total projected water demand for Subarea 0-4, for municipal and industrial purposes, is 7 mgd. The point of use is taken to be Ada.

The plan to supply the demand from the proposed transmission line from Clayton Reservoir to Subarea 0-2 is the most economical plan of supplying water from a multipurpose project. Transmission costs for the lateral main from the point of takeoff to the point of use, including annual operation and maintenance, are estimated to have a present worth of 3.2 cents per 1,000 gallons. The total estimated present worth of obtaining water from the proposed Clayton project, exclusive of storage, is 9.1 cents per 1,000 gallons, consisting of the cost of transmission to the takeoff point on the basis of a uniform gate rate, and transmission from the takeoff point to the point of use.

The alternative source of supply for this subarea is ground water from the Arbuckle limestone formation a few miles south of Ada. The Arbuckle group is the oldest limestone aquifer in Oklahoma. The maximum thickness of this group is about 6,700 feet. Potable water is found in about 200 square miles of the outcrop area, and in the subsurface formation near Sulphur. In the past, water from this aquifer has been used largely for farm supplies. More recently, however, several industrial firms have developed water supplies in the aquifer, several irrigation wells have been developed, and the city of Ada developed several wells to supplement the city's original supply from the Byrd's Mill Spring, which is also fed from this aquifer.58,62/

Wells developed in this aquifer have been reported to yield as much as 700 gpm from a 1,000-foot well, with little drawdown. Other wells in this aquifer yield from about 50 gpm to 2,000 gpm. Wells in the aquifer, where it is covered by younger sediments, appear to have yields proportionate to the depth of the well.62/

Total withdrawals at present appear to be a small portion of the total amount of water which could be yielded by this aquifer. Estimates indicate that possibly as much as 1 mgd per square mile of outcrop area could be obtained without depleting the aquifer. It is therefore most probable that an alternative ground water supply can be provided to meet the estimated demand of the subarea.58,62/

The estimated 1965 present worth of utilizing ground water as an alternative source of municipal and industrial water supply is 3.3 cents per 1,000 gallons, including development of the source, transmission, interest, and annual operation and maintenance.

The present worth of obtaining water from the alternative ground water source is less than transmission only, for the most economical means of obtaining water from one of the study projects. The demand for this subarea, therefore, may be supplied more economically from the alternative source and there is no anticipated demand for municipal and industrial storage in the Clayton or Tuskahoma Reservoirs for Subarea 0-4.

Subarea 0-5

The total demand of Subarea 0-5 for municipal and industrial uses in the year 2010 is projected to be 11 mgd, of which 4 mgd is assumed to be concentrated at Seminole and 7 mgd at McAlester for the purpose of estimating.

As in the preceding two subareas, the cost of supplying water from the proposed study reservoirs is based upon the uniform gate rate cost from the main transmission line to the Subarea 0-2 terminal storage plus the cost of transmission from the takeoff point to the point of use. The cost of obtaining water under this plan has a 1965 present worth of 7.0 cents per 1,000 gallons for the Seminole point of use and 6.6 cents per 1,000 for the McAlester point of use.

The alternative plan for supplying the Seminole demand is the development of ground water sources capable of providing 4 mgd. The principal aquifer in the area is the Vamoosa sandstone formation, which underlies most of Seminole County. The formation consists of about 250 to 300 feet of conglomerate, sandstone and shale, and provides municipal and industrial water to Seminole and several other municipalities. The formation is relatively undeveloped, therefore, it is assumed that the aquifer will be capable of supplying future needs without difficulty.62/

The 1965 present worth of developing sufficient ground water to meet the projected future demand of 4 mgd is estimated at 3.6 cents per 1,000 gallons.

Since the present worth of supplying the demand from local alternatives is less than transmission only, for the most economical method of supplying water from either Clayton or Tuskahoma Reservoir, the use of storage in these projects is economically infeasible and no demand on the projects is anticipated for this portion of Subarea O-5.

The alternative plan for supplying the McAlester demand consists of the development of a surface water source capable of yielding 7 mgd. There are several sites capable of yielding at least this much water; however, the alternative chosen is a site just north of McAlester on Coal Creek. It is estimated that the 1965 present worth of obtaining water from this alternative is 1.2 cents per 1,000 gallons, including capital expenditures for site development and transmission facilities, interest, and annual operation and maintenance.

Since the present worth of the alternative plan is less than the cost of transmission only, for the most economical plan of obtaining water from storage in one of the proposed study reservoirs, the use of water from the study reservoirs is not economically feasible and there is no anticipated demand on the projects from this subarea.

Subarea T-1

The total water demand of Subarea T-1 is projected to be 1,361 mgd by the year 2010, of which 954 is for municipal and industrial use and 365 for thermal power production consumptive uses. As pointed out in the discussion of requirements for thermal electric power production in the section entitled "Projected Water Demands," there will be water of low quality which is more than sufficient to provide for the projected requirement. Since some of the excess low-quality water could possibly be used for certain industrial purposes such as cooling, the total industrial and power component of the total requirements were divided on the basis that 20 per cent of these requirements would require water of equivalent quality to that for municipal requirements. The remaining 80 per cent could be of low quality, even return sewage flows from the municipal uses.

The requirements for low-quality industrial and thermal electric uses are shown graphically in Figure 13. Plotted on the same chart are the estimated quantities of water which are anticipated to be available for these uses. The Tennessee Colony Reservoir, located on the main stem of the Trinity River has an estimated yield at the present time of 370 mgd of which 100 mgd is return flow from the municipal treatment plants.[57,63] Based upon average return flow factors developed for the general area,[64] the return flow is estimated to be 50 per cent of the municipal use in that year or 637 mgd.

This is an additional 537 mgd over and above the return flow included in the present yield of the Tennessee Colony Reservoir. It is fairly obvious that sufficient water to meet the cooling portion of the industrial and thermal power requirements will be available since only 12 per cent of 65 mgd of the estimated future return flows would actually be required to make up the difference between existing sources of 40 mgd (based on present estimated water use) plus the present estimated yield of Tennessee Colony Reservoir, or a total of 410 mgd before considering future increments of return flow.

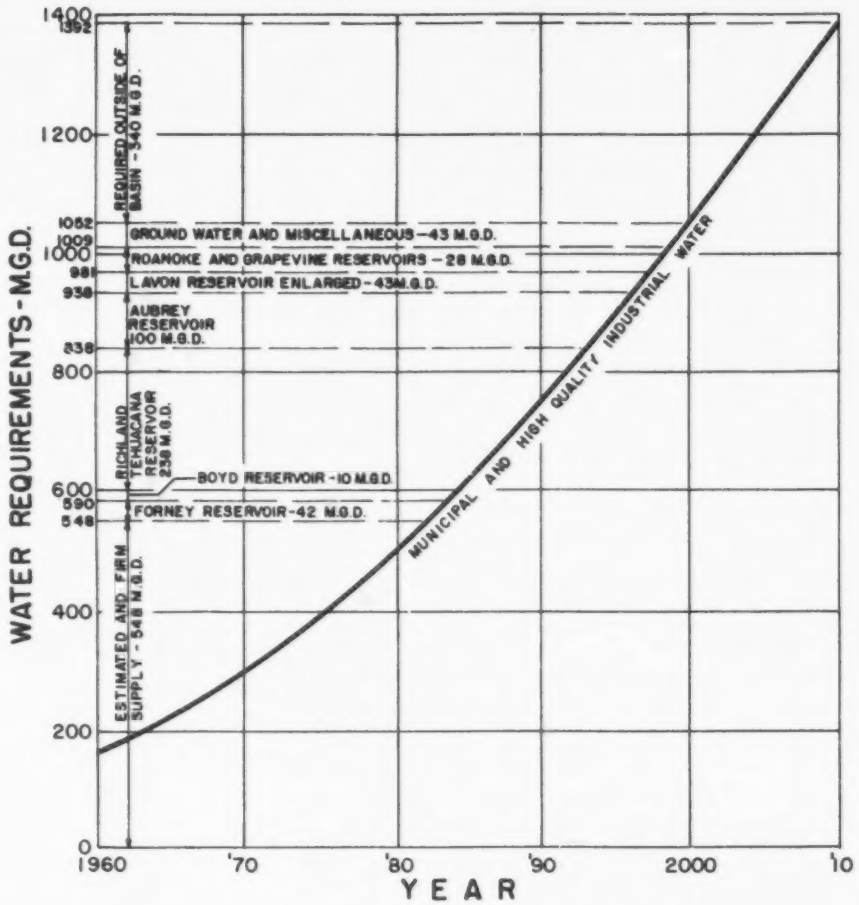
The municipal plus 20 per cent of the combined power and industrial requirements are therefore taken as the requirement which must be provided through the development of a water supply plan. These requirements are shown graphically in Figure 14. They amount to a projected total demand of 1,392 mgd by the year 2010. As previously stated, the present and firm sources of supply are estimated to be capable of providing 548 mgd of suitable quality water for these purposes. There is therefore a projected demand of 844 mgd with present sources becoming inadequate in 1980.

It is fairly certain, from both an economic and political point of view, that as much water as can be obtained from within the basin will be developed to meet these demands. The costs of transmission from out-of-basin sources are estimated to be higher than development within the basin. Complicated legal problems will arise with the interstate transfer of water which probably would, by itself, deter development of out-of-state sources until after the complete development of in-basin sources is accomplished.

Proceeding with this assumption, all in-basin sources are considered and found to be capable of yielding about 464 mgd of surface water suitable for municipal and high-quality industrial uses. In addition, there is some estimated 60 mgd of ground water available in the area of which some 20 mgd is already in use.[52,63,65,66]

The development of this ground water supply is not anticipated to have much impact upon the development pattern of surface water supplies for the subarea, since the amount is small in comparison with the total projected demand. Also, the surface water sources will, in all likelihood, supply the major demands which are concentrated in the Dallas-Fort Worth areas, whereas the ground water development is anticipated to serve small municipalities and individual firms. It is anticipated that ground water development will occur at some undetermined rate over the study period, and will be completely developed by the time that all other in-basin sources are completely developed.

The potential total development of all sources within the upper Trinity River Basin, which are suitable for municipal and high-quality industrial requirements, is estimated to be capable of yield-



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

ESTIMATED WATER REQUIREMENTS AND IN-BASIN SUPPLIES SUB AREA T-I

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m.f.k.

FIGURE 14

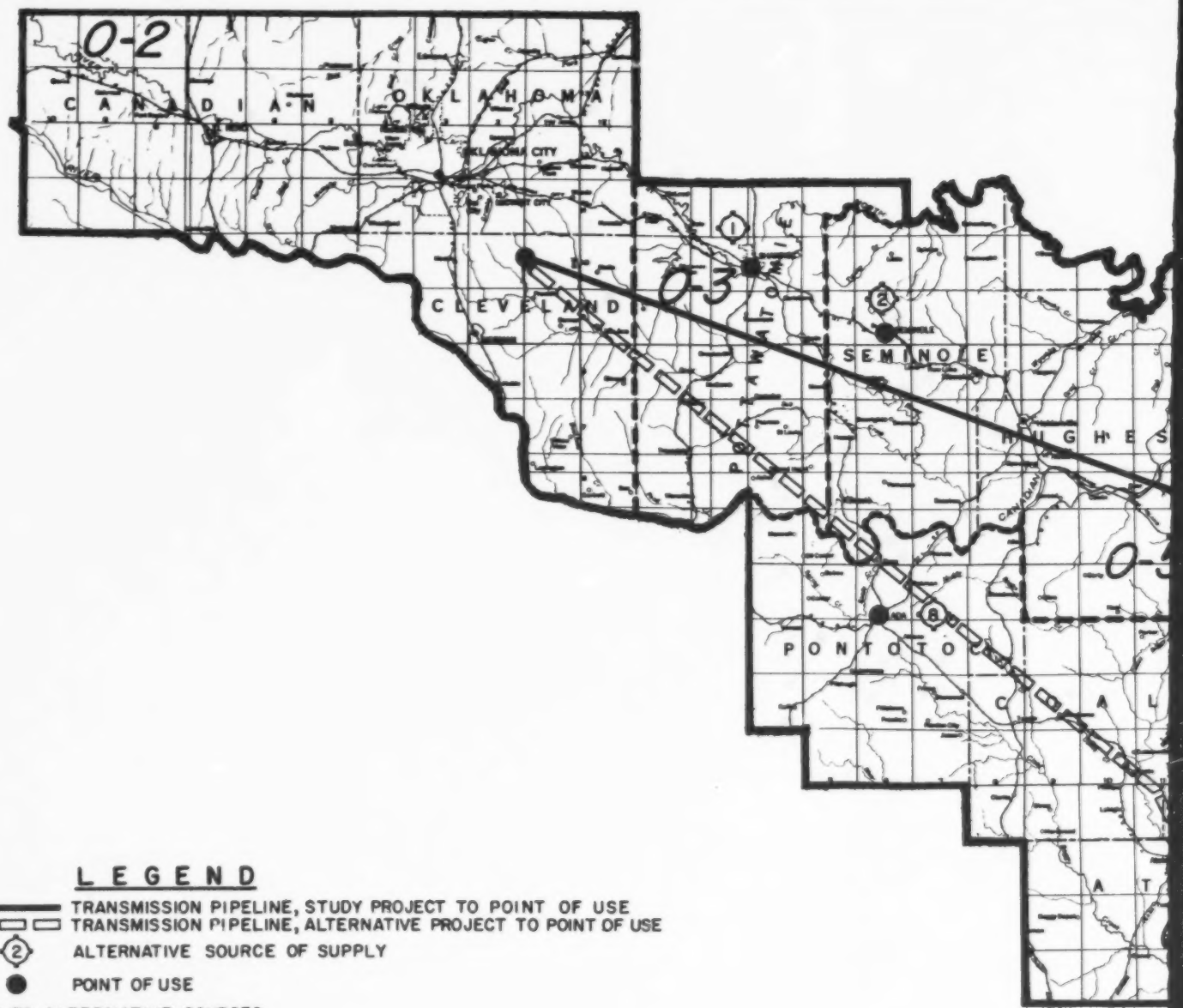
ing 1052 mgd in the year 2010. This takes into account reductions of yield expected because of decreased runoff caused by the anticipated Soil Conservation Service programs in the basin.[52,63,65,66] The total in-basin sources are anticipated to be inadequate in the year 2000.

The potential demand which must be satisfied with water from sources outside the upper Trinity Basin is estimated to be about 340 mgd in the year 2010, with the demand beginning in the year 2000.

An examination of alternative sources of supply capable of meeting this demand indicates that more satisfactory sources than Hugo are available. Therefore, there is no demand for, and no economic value attributable to, water supply storage in the Hugo Reservoir to meet the demands of Subarea T-1. The alternatives considered will be discussed in detail in the forthcoming comprehensive water resources study of southeastern Oklahoma and adjacent areas.

Subarea T-2

Since there is no projected demand for municipal and industrial water in Subarea T-2, there are no alternative plans to be developed.



LEGEND

TRANSMISSION PIPELINE, STUDY PROJECT TO POINT OF USE

TRANSMISSION PIPELINE, ALTERNATIVE PROJECT TO POINT OF USE

(2) ALTERNATIVE SOURCE OF SUPPLY

POINT OF USE

KEY TO ALTERNATIVE SOURCES

1. PECAN CREEK SITE
2. GROUND WATER, VAMOOSA SANDSTONE
3. COAL CREEK SITE
4. MC GEE CREEK SITE
5. BUCK CREEK SITE
6. TEN MILE CREEK SITE
7. KIAMICHI LOW DAM SITE
8. GROUND WATER, ARBUCKLE LIMESTONE

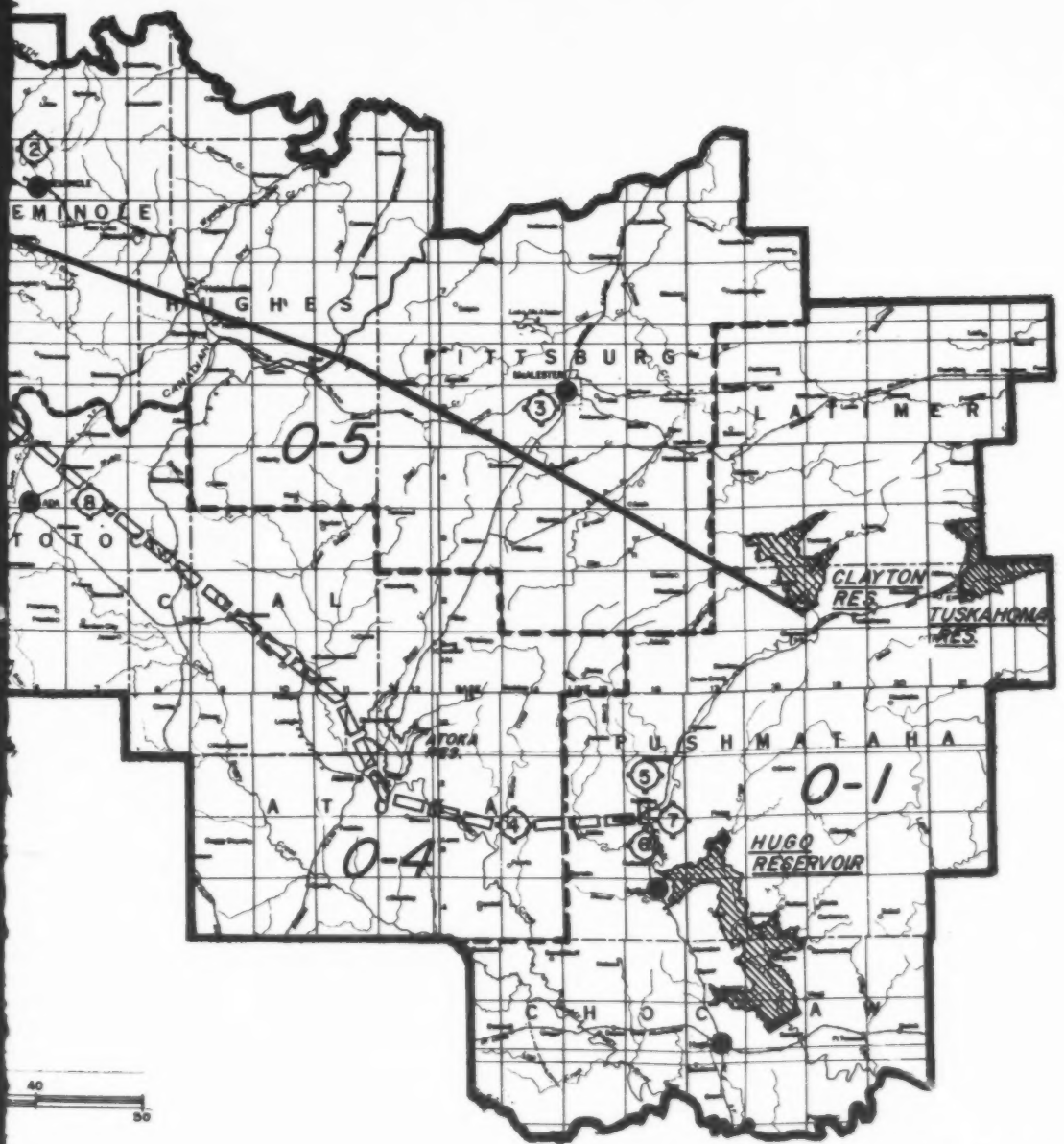
0-2 SUB-AREA

SUB-AREA BOUNDARY

SCALE

0 20 40

40 80 120



HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

LOCATION MAP

OKLAHOMA

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FIGURE 15

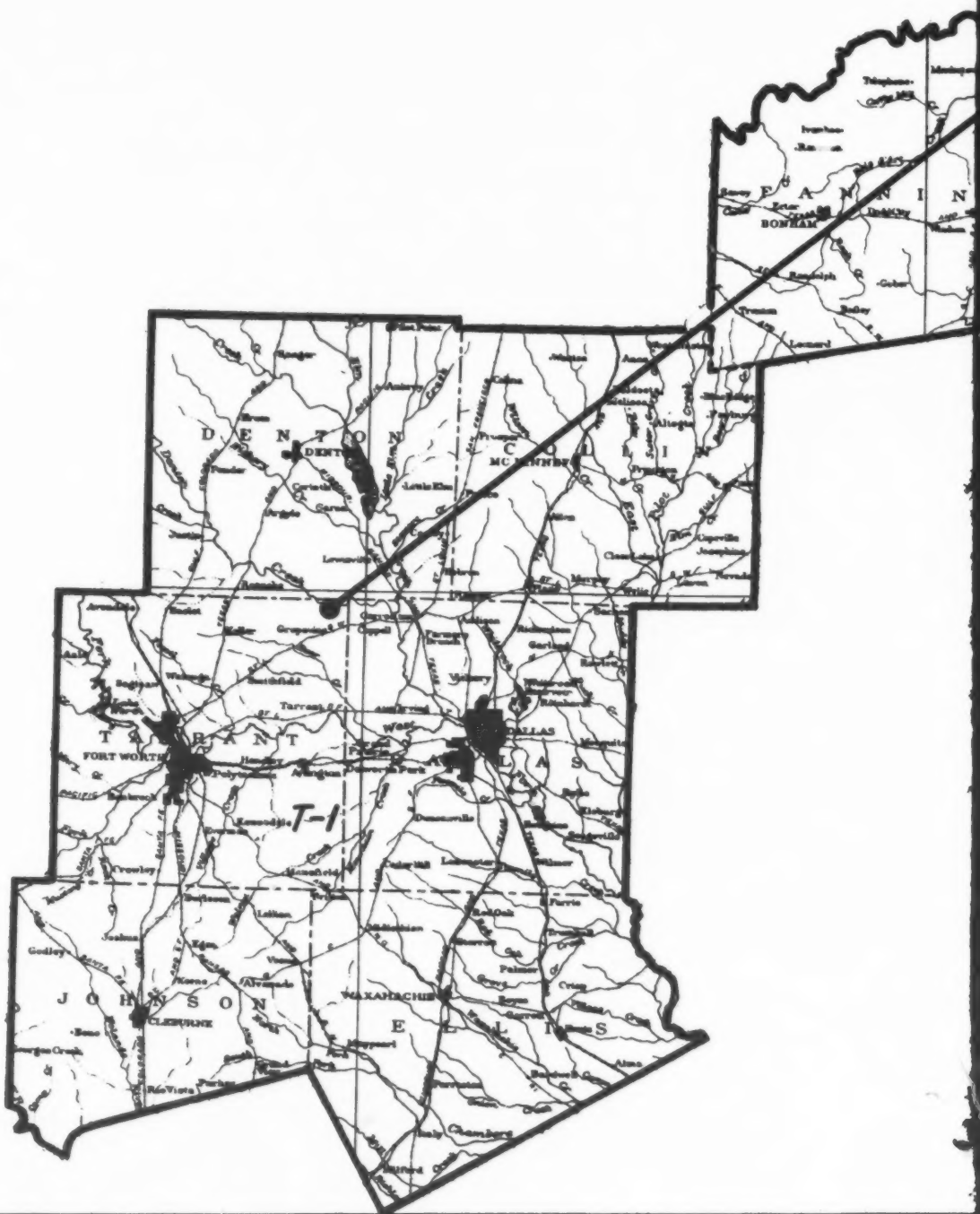
LEGEND

TRANSMISSION PIPELINE, STUDY AREA TO POINT OF USE

T-2 SUB-AREA

SUB-AREA BOUNDARY

POINT OF USE



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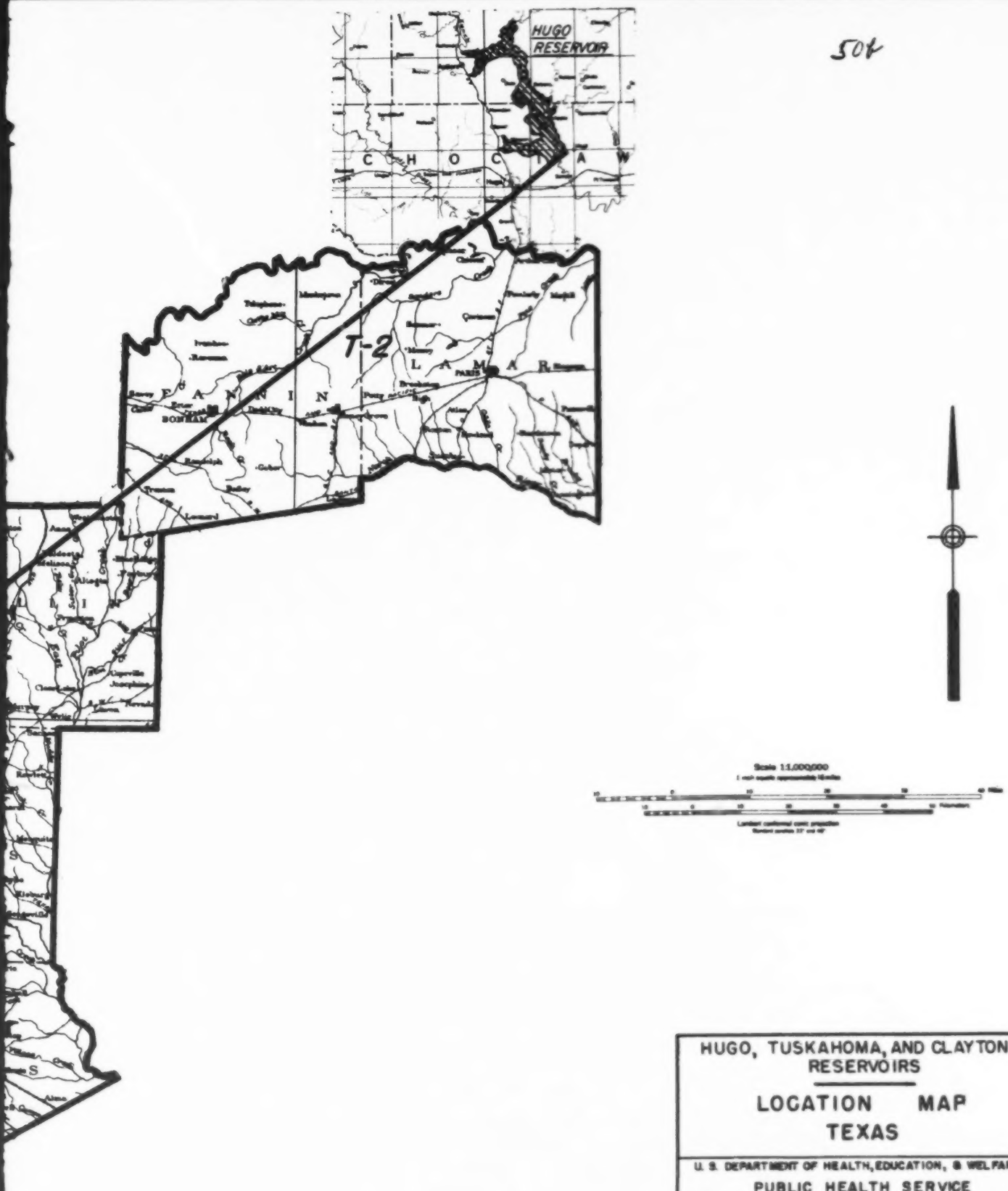

HUGO, TUSKAHOMA, AND CLAYTON RESERVOIRS

LOCATION MAP

TEXAS

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FIGURE 16

IX. VALUE OF STORAGE

The value of storage for municipal and industrial water supply purposes is determined on the basis of the most economical alternative plan capable of meeting the projected demand. The costs of the plans considered were presented in Table 18 in the previous section of this report. The value of storage for the anticipated demand on the project is presented in Table 20.

Table 20

Value of Water Supply Storage in Hugo, Tuskahoma, and Clayton Reservoirs

	Hugo	Clayton	Tuskahoma
Yield, mgd	35	160	200
Year of First Use	1965	1980	2000
Average Annual Value as Present Worth in:			
Year of First Use	$68,000	$375,000	$395,000
1965	68,000	208,000	100,000
Average Value, Cents per 1 000 Gallons Firm Yield, as Present Worth in:			
Year of First Use	0.53	0.64	0.54
1965	0.53	0.36	0.14

The best interests of the study area, from a water supply standpoint, would be served by deferral of the Clayton and Tuskahoma Reservoirs. The value of storage and the anticipated year of first use indicate that the best utilization of resources could be accomplished by such deferral. There are many uncertainties involved in making forecasts; the uncertainties becoming more significant as the projection moves farther into the future. Deferral of projects for which early construction is not foreseen at the present time offers the opportunity of restudying the projects at periodic intervals in the future, providing flexibility and resultingly better resource development. This advantage is foregone once the project becomes a reality.

The plan of development indicated by the results of this study indicates the immediate construction of Hugo Reservoir with storage capable of supplying 35 mgd. Because of the large volumes of water which could be yielded from full development of the site, and the possibility that such water will be required at sometime in the far distant future, it is the opinion of the Public Health Service that water supply storage to yield 35 mgd should not be a deciding factor in the determination of the construction date of the Hugo Reservoir.

It is felt that a future potential of such magnitude should not be precluded for such a short-range objective. The development of the Hugo project to such a small percentage of its full potential is not recommended because of the loss of a dam site which could conceivably contribute much more in the way of benefits in the distant future. It is recommended that the storage indicated by this study be provided only if the project is to be constructed in the near future for some other purpose regardless of water supply considerations.

Following Hugo in the indicated plan of development would be Clayton Reservoir, to be completed by 1980 with storage capable of providing 160 mgd, and finally Tuskahoma, to be completed by 2000, with storage capable of yielding 200 mgd.

As previously mentioned, these dates are subject to an increasing uncertainty factor according to their proximity to the year 2010. In addition, the plan of construction is dictated solely by water supply considerations. Should construction of the projects at some earlier date for other purposes be indicated, it is recommended that the water supply storage be included at that time in order to preserve an excellent source of high-quality water.

A major problem which arises with the deferral of projects is the effect of changed land uses on the construction of the project. Often, more intensive and more highly developed uses of the reservoir sites can make costs prohibitive and the future construction of the project impossible. It is recommended that the Corps of Engineers consider the problem of preserving the sites for future development. One method of accomplishing this preservation, which has been practiced successfully in the field of timber resources, is Federal government purchase of the land now, with the land leased for specific uses until the project is ready for construction. This plan provides income to defray the cost of purchasing the land at the present time and permits Federal control of land uses and their effect on the future dam construction.

Clayton Reservoir

The value of municipal and industrial water supply storage in the Clayton Reservoir is based upon a demand for the full yield of 160 mgd supplied to terminal storage in Subarea 0-2. The cost of transmission only, from the Clayton multipurpose project, is deducted from the cost of the most economical alternative plan to provide the present worth of the storage after adjusting for transmission. In this case, the most economical alternative is a single-purpose reservoir at the same site. The cost differential is $10,400,000 which is attributable to storage. Based upon first use of storage from the multipurpose Clayton project in 1980, the average annual value of storage has a 1965 present worth of $208,000 or $1,300 per mgd of firm yield.

Tuskahoma Reservoir

The value of municipal and industrial water supply storage in the Tuskahoma Reservoir is based upon a demand for the full 200 mgd of yield supplied to terminal storage in Subarea 0-2. In this case, the most economical alternative plan is also a single-purpose reservoir at the same site. The differential cost between the plans which is attributable to storage in the proposed Tuskahoma multi-purpose reservoir is estimated to have a 1965 present worth of $10,970,000, based on 1980 utilization. This represents an annual average value of storage in the Tuskahoma project of $219,400 per year which is $1,097 per mgd of firm yield. However, since the construction of Tuskahoma in 1980 in effect provides an overlap in supply for the same demand considered to be provided from Clayton, and since there is a higher value attributable to Clayton over the study period, it would appear that the Tuskahoma Reservoir is not, in fact, needed in 1980, but rather is not required until 2000, assuming the prior construction of Clayton. Even though the projected demand by the year 2010, after subtracting Clayton, does not quite reach 200 mgd, it is recommended that the reservoir be developed to capacity. The 1965 present worth of the value of storage, readjusted to provide for the first use of storage in Tuskahoma Reservoir in the year 2000, is estimated to be $100,000 average annual.

Hugo Reservoir

The value of storage capable of providing 35 mgd to Subarea 0-1, with first use of storage in 1965, is based upon an alternative plan calling for the development of local sources of supply. The value attributable to this quantity of storage has a 1965 present worth of $68,000 average annual over the 50-year economic life of the project.

The values of storage presented above are calculated without considering the Red River as an alternative source of supply because of its present poor quality. However, the Public Health Service and the Corps of Engineers, in conjunction with State and other Federal agencies, are presently studying the sources of pollution with the objective of devising corrective measures which would prevent these minerals from entering the Red River. The prospect of imminent improvement in the quality of Red River water would call for a reappraisal of the conclusions of this report, since the Red would then become a significant potential source of municipal and industrial water, the division of such water to be determined by an interstate compact of participating states.

X. STREAM QUALITY MAINTENANCE

Comprehensive water resource management includes the means of satisfying existing and projected demands for water and for satisfactory disposal of wastes produced through its use. There should be no question that water use carries with it the responsibility of considering downstream users' interests in both quantity and quality. Maintenance of stream quality is an inseparable part of a complete water resource program.

The by-products of water use, i.e., liquid wastes, whether treated or not, historically have been discharged to streams, rivers, lakes, or marine waters. Disposition of wastes is also accomplished by discharge to lagoons, from which there is no surface overflow, or to underground formations. In many instances the stream plays a dual role of water supply and waste disposal, with wastes returned to the stream below the point of withdrawal. At times, water supply is obtained from one river basin and the resulting wastes released into another basin. In the latter instance, the flow downstream from the point of withdrawal is permanently decreased since return flows of liquid wastes have been shunted to another watershed and are not available to supplement the remaining natural flows. Whatever the method, the results affect the future development of the region in which disposition is made.

Planners for areal or regional growth must determine future goals and provide for waste disposal in a manner that will not jeopardize achievement of these goals. They are faced with two choices, each with its price tag: (1) sacrifice of quality and designation of receiving streams as conduits for the transport of wastes; or (2) the preservation to a reasonable degree of the quality of waters into which wastes are discharged.

Either choice may have a high cost. Degradation of water quality to a point where its usefulness is seriously lessened or destroyed may result in a ceiling being placed on development of the area adjoining the degraded stream. In the long run, the ultimate cost of this choice may far exceed the cost of preserving stream quality. It is recommended, therefore, that the second choice be made and necessary steps taken to protect the quality of downstream waters.

Methods for achieving the stream quality maintenance goal must be considered. A body of water can receive and assimilate, without undue damage, only so much waste under given conditions of flow, temperature, and existing quality. Preserving stream quality, then, becomes a problem of proportioning the discharged waste loadings to stream flow so that the assimilative capacity of the stream is not exceeded. Given a fixed stream flow, the maximum waste load that can

be tolerated is also fixed. In a growing area with attendant increasing waste production, two possible answers are evident - either the wastes must be subjected to a sufficiently high degree of treatment so that the residual waste load can be discharged without causing excessive damage to the stream, or a limit must be placed on areal growth (and waste production) so that the stream can accept the wastes without having its quality lowered to an unreasonable degree.

Substances added to water as it is used cause the decrease in quality. Additives may be separated into two broad categories - organic and inorganic. Today, 85 per cent reduction of the organic load is reasonable and is achieved with conventional biological treatment processes. It does not seem unreasonable to expect that the efficiency of these processes can be raised to at least 90 per cent within a 50-year period. However, oxidation of organic solids does not reduce inorganic solids of which chlorides are representative. While removal of dissolved inorganic solids such as chlorides can be accomplished, costs are so high ($500 per million gallons and up) that this treatment is not practicable for large volumes of waste waters.

In this study, two degrees of waste treatment have been considered: secondary treatment which reduces the biochemical oxygen demand of wastes 85 - 90 per cent and tertiary treatment which accomplishes the reduction of the biochemical oxygen demand beyond 90 per cent.

At least secondary treatment should be provided for wastes arising from water use. With this accomplished, the needs and means for providing further treatment must be examined and additional long-range goals considered. If the proposed receiving waters already carry a load of dissolved inorganic solids of such magnitude that they are generally unsuitable for municipal and industrial use but do support fish life and provide recreational facilities, the removal of all, or part of, the residual 10 per cent of oxidizable matter may be adequate to protect these interests.

Prevention of damage by the discharge of inorganic solids, if required, necessitates consideration of methods of accomplishment. There are two possible approaches - removal of these inorganics by ion exchange at costs cited above or addition of low-solids water to the receiving stream in quantities sufficient to reduce the solid concentrations in the receiving stream to desired levels. The present quality of the South Canadian River[67] at Bridgeport, Oklahoma, makes it generally unsuitable for municipal and industrial requirements. However, fish life can be supported and recreational opportunities provided if its assimilative capacity for oxidizable matter is not exceeded. Chlorides at this station are not excessive, being

generally well under the Public Health Service recommended drinking water standard of 250 ppm for the major part of the year. Hardness also is high and recommended standards for total dissolved solids of 500 ppm are exceeded the greater part of the year. Assuming that wastes from Oklahoma City's metropolitan area, which cannot be assimilated by the North Canadian and Deep Fork Rivers, will be discharged to the South Canadian River, it is concluded that only treatment to remove the major portion of the 10 per cent residual load of oxidizable materials is justified at this time and storage in the Kiamichi River projects for low-flow augmentation should not be provided. A major population and industrial growth in the area through which the South Canadian River flows is not believed probable; however, if growth does occur and if present concentrations of inorganic materials are suitably reduced, augmentation of low-stream flows to maintain the quality of the river at reasonable levels will become highly desirable.

Consideration has been given to requirements for low-flow augmentation in the event that the decision is made to maintain stream quality with respect to both organic and inorganic loads. From this study, it is evident that there are two areas of water demand - Oklahoma City metropolitan area with a projected requirement of 436 mgd and the area adjacent to the Hugo Reservoir with a requirement of 35 mgd.

Based on data from other studies made in greater detail by the Public Health Service,[68,69] it is estimated that 1½ gallons of stream flow would be required for each gallon of water demand in the Oklahoma City area. With a projected water demand of 436 mgd in the year 2010, this means a flow of about 644 mgd in receiving streams would be required to assimilate wastes for which only secondary treatment has been provided. In the Hugo area, the second area of major demand, 25 mgd of stream flow would give reasonable assurance that the quality of the water in the receiving stream will be maintained at acceptable levels.

The cost of water from the Hugo, Tuskahoma, and Clayton Reservoirs delivered to the Oklahoma City metropolitan area is too high to justify its use for low-flow augmentation and storage in these reservoirs for this purpose is not justified. Other sources of water for stream quality maintenance and the economics of their development will be considered in the study now under way of a larger region which encompasses the demand areas of this report.

In the Hugo area the greater part of the industrial water demands are for a projected pulp and paper mill (20 mgd out of a projected industrial demand of 23 mgd). Previous studies[68,69] indicate that one part stream quality maintenance water to each part of the industrial demand will be adequate. Hence, the provision of 25 mgd

for water quality maintenance gives reasonable assurance that the quality of the receiving stream will not be unreasonably lowered. It is important that pulp and paper production projects for the Hugo area be located below the proposed Hugo Reservoir - to place them upstream would degrade the quality of water impounded by the dam. Below the dam, wastes will quickly reach the Red River, a relatively large stream. Prospective waste discharges into the Red River from the Kiamichi will be one factor in the overall problem of maintaining satisfactory quality in the Red. This also will be considered in greater detail in the comprehensive study previously mentioned.

Protection of the quality of State waters is primarily the responsibility of four Oklahoma State agencies: the Water Resources Board, the Board of Health, the Fish and Game Commission, and the Corporation Commission. As previously discussed, augmentation of low stream flows may be selected as the preferred method of maintaining stream quality. Although the final determination and acceptance of stream quality must come from the above-listed State agencies, it is believed that the maintenance of stream flows at levels indicated will result in quality conditions reasonably acceptable to them.

Consideration of water demands and waste disposal requirements in the study area must include recognition of the problem which may arise when large quantities of low-solids water are prevented from reaching the main stem of the Red River from its tributaries. It is probable that the quality of Red River below its confluence with the Kiamichi will be significantly lowered since, with low-solids water withheld, the remaining flow would have a higher dissolved solids content. The Public Health Service, in cooperation with the Corps of Engineers, is presently studying the feasibility of removing natural pollution from the Red and Arkansas River Basins. To what extent transporting waters of the Kiamichi River out of the Red River will bear on the results of this study cannot be clearly seen at this time. There is little question, however, that the results of the Ark-Red study will be significantly affected by the transfer of good-quality water to users outside the Red River Basin.

EXHIBIT A

Cities Visited and Agencies, Institutions and Industries Contacted

Cities Visited

Oklahoma

Ada	Idabel	Purcell
Antlers	Konawa	Shawnee
Bethany	Lindsay	Seminole
Broken Bow	Madill	Stillwater
Clayton	McAlester	Tecumseh
Coalgate	Midwest City	Tishomingo
Del City	Norman	Valliant
Edmond	Nichols Hills	Wewoka
Holdenville	Oklahoma City	Wilburton
Hugo	Pauls Valley	Wright City

Texas

Bonham	Dallas	Paris
Clarksville	Fort Worth	

Agencies, Institutions and Industries Contacted

U. S. Bureau of Reclamation
U. S. Geological Survey
U. S. Soil Conservation Service
Agriculture County Agents
Oklahoma Corporation Commission
Oklahoma Department of Commerce and Industry
Oklahoma Employment Security Agency
Oklahoma Geological Survey
Oklahoma Soil Conservation Service
Oklahoma State Board of Health
Oklahoma State University
  Forestry School
  Geology and Geography Department
  Agricultural Economics Department
  College of Business
Oklahoma Water Resources Board
Southeastern Oklahoma College
Texas Employment Commission
Texas State Department of Health
University of Oklahoma
  Bureau of Water Resources Research
  Bureau of Business Research
University of Texas
  Bureau of Economic Geology
  Bureau of Business Research
  Department of Civil Engineering
Chambers of Commerce
City Managers or Mayors
City Water Superintendents
Consulting Engineers
Continental Oil Company
DeGolyer and MacNaughton
Dierks Forestry Company
Humble Oil Company
Lone Star Steel Company
McAlester Fuel Company
Phillips Petroleum Company
Public Utilities Companies
Sinclair Oil Company
Miscellaneous Small Industries

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EXHIBIT B-1

Cost Data Utilized in Determining Value of Storage

A. Capital Costs

1. Dams and reservoirs (costs include land, dam, rip-rap, spillway and intake, but do not include piping or pumping facilities)

   a. Small projects in eastern Oklahoma - $35.00 to $37.00 per acre-foot of storage

   b. Specific projects:

Name	Capacity Ac.-Ft.	Estimated Cost 1960 Dollars
McGee Creek	240,000	$2,000,000
Buck Creek	150,000	6,200,000
Ten Mile Creek	150,000	6,000,000
Kiamichi Low Dam	100,000	200,000
Tuskahoma, Single Purpose	231,000	7,630,000
Clayton, Single Purpose	183,000	7,300,000
Pecan Creek	44,400	1,200,000

2. Ground water (drilling, testing, casing, screen, pumps, well house and piping to distribution system) - cost variable depending upon soil type, depth, diameter, distance from point of use, etc. - range: $10,000 to $60,000 per well

3. Transmission facilities

   a. Pumping (pumps, motors, pump house and all appurtenances necessary for operation) - $125.00 per installed horsepower

   b. Transmission pipeline (in-place cost including valves, fittings, etc., and allowances for special construction) - concrete pressure pipe

Pipe Size	Cost, $ per Mile
96 inch	$587,000
90 "	545,000
84 "	500,000
72 "	375,000
60 "	280,000
30 "	100,000
24 "	80,000
20 "	65,000

EXHIBIT B-2

B. Annual Costs

1. Non-Federal interest rate - 4%

2. Economically useful life

   a. Dams, reservoirs and pipe lines - 50 years

   b. Wells, pumping equipment, etc. - 25 years

3. Operation and maintenance

   a. Dams and reservoirs

      (1) Small projects, storage less than 50,000 acre-feet - 1% of initial capital cost per annum

      (2) Projects over 50,000 acre-feet - 0.5% of initial capital cost per annum

   b. Ground water - 4 to 5% of initial capital cost per annum

   c. Transmission pipe line

Pipe Size	Annual Cost Per Mile
30" and less	$ 75.00
36" to 54"	100.00
60" to 72"	150.00
78" to 84"	200.00
90" to 96"	250.00

   d. Pumping plant

      (1) All operation and maintenance except power - 5-3/4% of initial capital cost per annum

      (2) Electric energy cost

         (a) Large installations - 8 mills per kwhr

         (b) Small installations - 12 mills per kwhr

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